

***Saussurea weberi* Hultén (Weber's saw-wort):
A Technical Conservation Assessment**



**Prepared for the USDA Forest Service,
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Species Conservation Project**

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COVER PHOTO CREDIT

Saussurea weberi (Weber's saw-wort). Photograph by Hollis Marriott.

SUMMARY OF KEY COMPONENTS FOR CONSERVATION OF *SAUSSUREA WEBERI*

Status

Saussurea weberi (Weber's saw-wort) is a rare plant species known from disjunct occurrences in alpine habitats across the middle Rocky Mountains, from central Colorado to southwestern Montana. *Saussurea weberi* is known from portions of the Pike, Arapaho, and Shoshone national forests in USFS Region 2, the Beaverhead-Deerlodge National Forest in USFS Region 1, and the Bridger-Teton National Forest in USFS Region 4. All occurrences on the Arapaho National Forest are on lands administered by the White River National Forest.

Saussurea weberi currently has no federal status under the Endangered Species Act (U.S.C. 1531-1536, 1538-1540) or in Region 2 of the USDA Forest Service (USFS), but is listed as a sensitive species in USFS Regions 1 and 4, and is also listed as a sensitive species by the Bureau of Land Management in Colorado. NatureServe assigns *S. weberi* a global rank of G2G3 (between imperiled and vulnerable, NatureServe 2003). *Saussurea weberi* is considered imperiled (S2) in Wyoming (NatureServe 2003, Wyoming Natural Diversity Database 2003a, 2003b), based on six element occurrence records (EORs) and is recognized as a regional endemic with a medium conservation priority. The species is considered imperiled (S2) in Colorado (Colorado Natural Heritage Program 2003b, NatureServe 2003), which recognizes 17 EORs. *Saussurea weberi* is considered critically imperiled (S1) in Montana (Montana Natural Heritage Program 2003b, NatureServe 2003) based on one EOR. Within USFS Region 2, both of the Shoshone NF populations are in the Fitzpatrick Wilderness, while one of the 14 occurrences in Colorado is in the Hoosier Ridge Research Natural Area (RNA) on the Arapaho National Forest (administered by White River National Forest).

Primary Threats

Saussurea weberi is thought to have a naturally limited range and is not known to have suffered significant population or habitat loss as a result of human activities. However, distribution information may not be complete and little is known about the basic ecology and biology or environmental requirements of *S. weberi*, and there are limited data regarding population trends. The species' rarity is likely due in part to discontinuous habitat availability across a limited geographic range and restricted habitat requirements, which are also responsible for its inherent ecological and geographic vulnerability. Human activities may pose threats to individual occurrences and, if not properly managed, may adversely impact the long-term survival of the species. *Saussurea weberi* is vulnerable to management practices that affect the quality and quantity of its habitat.

Rangewide threats to *Saussurea weberi* are due mainly to potential climate change and environmental stochasticity. Ultimately, warming associated with global climate change may pose the greatest threat to this and other alpine species. Human-related threats are generally low across the range of *S. weberi* and in most of Region 2, although some of the occurrences on USFS lands in Colorado may be at greater risk, as are the two occurrences on private land in Colorado. Primary threats include off-road vehicle (ORV) use, mining activities (including associated road and other mine-related construction), and other construction, including residential development on private land. All of the occurrences in Wyoming and Montana are within designated wilderness areas, which greatly reduce the potential for damage from ORVs, since motorized vehicles are not permitted in wilderness areas. Activities such as livestock and non-motorized recreational activities currently pose minor threats, as many occurrences are not in active grazing allotments and most occurrences are not in areas that favor grazing. Livestock and non-motorized recreational activities may potentially pose more serious threats in the future if management policies change or the intensity of use increases. Invasive weeds do not appear to pose a threat at present. Management-related threats to USFS Region 2 occurrences are generally low, but include potential for damage by ORVs, mining activities and associated road construction, livestock trampling and possibly herbivory, and non-motorized recreational activities such as hiking.

Primary Conservation Elements, Management Implications, and Considerations

An appropriate conservation approach would aim at identifying and preserving habitat, avoiding impacts to known occurrences (i.e., minimizing surface disturbance, maintaining important habitat microenvironmental conditions) and identifying the research needed to provide a better understanding of population trends, life history,

reproductive ecology, and autecology, with the goal of more effective management. In Wyoming, most of the suitable habitat (i.e., calcareous alpine areas) on lands administered by the USFS has been surveyed, with a few minor exceptions (Marriott 1991, Scott personal communication 2003). In Colorado, unsurveyed potential habitat remains, including portions of the Sawatch Mountains on lands administered by USFS in the Gunnison National Forest (Johnston personal communication 2003) and the San Juan Mountains in the San Juan National Forest. Johnston (personal communication 2003) estimates that as little as 50 percent of the potential suitable habitat has been searched in Colorado.

Primary conservation elements, management implications and considerations are derived from the inherent risks to small, narrowly distributed populations that characterize some naturally rare taxa. USFS management considerations include assessing the need for designating *Saussurea weberi* as a sensitive species, assessing the need for a land exchange to protect the largest known occurrence in Colorado, preserving and resurveying known occurrences, surveying additional potential habitat, monitoring existing occurrences to determine trends, conducting pre-project surveys, and initiating basic demography studies.

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INTRODUCTION

This assessment is one of many being produced to support the Species Conservation Project for the Rocky Mountain Region (Region 2) of the USDA Forest Service (USFS). *Saussurea weberi* is the focus of an assessment because it is a rare species that is known to occur on national forests in Region 2. Within the National Forest System, a sensitive species is a plant or animal whose population viability is identified as a concern by a Regional Forester because of significant current or predicted downward trends in abundance or in habitat capability that would reduce its distribution (FSM 2670.5(19)). A sensitive species may require special management, so knowledge of its biology and ecology is critical. Although *S. weberi* presently has no formal status within USFS Region 2, it may be considered for future designation as regional sensitive species lists or Management Indicator Species lists are updated (Kratz personal communication 2003).

This assessment addresses the biology of *Saussurea weberi* throughout its range in Region 2, which encompasses a large portion of the species' global distribution. This introduction defines the goal of the assessment, outlines its scope, and describes the process used in its production.

Goal

Species conservation assessments produced as part of the Species Conservation Project are designed to provide forest managers, research biologists, and the public with a thorough discussion of the biology, ecology, conservation status and management of certain species based on available scientific knowledge. The assessment goals limit the scope of the work to critical summaries of scientific knowledge, discussion of broad implications of that knowledge, and outlines of information needs. The assessment does not seek to develop specific management recommendations. However, it does provide the ecological background upon which management must be based, and it focuses on the consequences of changes in the environment that result from management (i.e., management implications). Furthermore, it cites management recommendations proposed outside of Region 2 and examines the success of management plan implementations both within and outside of Region 2.

Scope and Information Sources

This assessment examines the biology, ecology, conservation status, and management of *Saussurea*

weberi with specific reference to the geographic and ecological characteristics of the USFS Rocky Mountain Region (Region 2). Similarly, this assessment is concerned with the reproductive biology, population dynamics, and other characteristics of *S. weberi* in the context of the current environment rather than under historical conditions. The evolutionary environment of the species is considered in conducting the synthesis, but in a current context.

In producing the assessment, all available information was reviewed, including refereed literature, non-refereed publications, research reports, personal communications, and data accumulated by state natural heritage programs, resource management agencies, and independent researchers. The assessment emphasizes refereed literature to the extent possible, because this is the accepted standard in science; however, refereed literature pertaining specifically to *Saussurea weberi* is limited, consisting mainly of taxonomic descriptions and generalized discussions of distribution and range. As a result, the use of non-refereed literature, mainly herbaria records and Wyoming, Colorado, and Montana natural heritage program data was essential in developing this assessment. Unpublished data (e.g. Wyoming, Colorado, and Montana natural heritage program records) were important in estimating the geographic distribution and assessing habitat characteristics. Ron Abbott, independent botanist, provided much useful observational information regarding various aspects of the biology and life history of *S. weberi* derived from his on-going studies of the Horseshoe Cirque occurrence in Colorado's Mosquito Range. These data were applied with consideration of the limitations associated with the diversity of persons and methods used to collect the data.

The requirement to produce this assessment within a short time limited the ability to analyze unpublished data, and also to conduct meta-analysis synthesizing information from published literature. Other potential limitations of this assessment include a heavy reliance on state natural heritage program data and reports, and personal communications, because refereed publications pertaining to *Saussurea weberi* were few in number and general in nature. However, the Wyoming Natural Diversity Database and Colorado Natural Heritage Program botanists responsible for the data collection and management over the years are generally very experienced and highly regarded. Some of the older CNHP EORs lack detailed data, while some also contain potentially inaccurate or questionable comments (e.g., "wetland on rocky slope") (Colorado Natural Heritage Program 2003b).

Many of the element occurrences are documented with voucher specimens.

Treatment of Uncertainty

Science represents a rigorous, systematic approach to obtaining knowledge. Competing ideas regarding how the world works are measured against observations. However, because our descriptions of the world are always incomplete and our observations are limited, science focuses on approaches for dealing with uncertainty. A commonly accepted approach to science is based on a progression of critical experiments to develop strong inference (Platt 1964). However, it is difficult to conduct experiments that produce clean results in the ecological sciences. Often, observations, inference, good thinking, and models must be relied on to guide our understanding of ecological relations. Confronting uncertainty then is not prescriptive. In this assessment, the strength of evidence for particular ideas is noted, and alternative explanations are described when appropriate.

The greatest challenge encountered in developing this assessment was the lack of published information pertaining to the specific biology and ecology of *Saussurea weberi*. Much of the discussion of these topics in this document is derived from state natural heritage program data and reports as well as inferential data adapted from the generic and tribal level (i.e., *Saussurea* and *Cardueae*). Additionally, much of the discussion relating to threats and management issues was derived from personal communications with knowledgeable individuals affiliated with the land management agencies, the Colorado Natural Heritage Program (CNHP), and the Wyoming Natural Diversity Database (WYNDD). A Masters thesis and CNHP study investigating the pollination of *S. weberi* provided insight to the pollination aspects of reproductive biology for the species.

Publication of Assessment on the World Wide Web

To facilitate their use in the Species Conservation Project, species assessments are being published on the USFS Region 2 World Wide Web site. Placing the documents on the web makes them available to agency biologists and the public more rapidly than publishing them as reports. More important, it facilitates their revision, which will be accomplished based on guidelines established by USFS Region 2.

Peer Review

Assessments developed for the Species Conservation Process have been peer reviewed prior to release on the Web. This assessment was reviewed through a process administered by the Center for Plant Conservation, employing at least two recognized experts on this or related taxa. Peer review was designed to improve the quality of communication and to increase the rigor of the assessment.

MANAGEMENT STATUS AND NATURAL HISTORY

Management Status

Saussurea weberi has no special status in USFS Region 2 (Kratz 2003 personal communication; **Table 1**). *Saussurea weberi* is listed as a sensitive species in USFS Region 4, where it is known from the Bridger-Teton National Forest in Wyoming (USDA Forest Service Intermountain Region 1989). *Saussurea weberi* is also listed as a sensitive species in USFS Region 1, where it is known from the Beaverhead-Deerlodge National Forest in Montana (Montana Natural Heritage Program 2003a). *Saussurea weberi* is listed as a sensitive species in Colorado by the BLM (Bureau of Land Management 2000). NatureServe assigns *S. weberi* a global rank of G2G3 (NatureServe 2003). This rank is assigned because the plant is only known from 24 recognized element occurrences that are restricted to small areas of suitable (generally calcareous) alpine habitat in Colorado, Wyoming, and Montana (NatureServe 2003). The G2G3 listing (globally imperiled/vulnerable) suggests there is uncertainty about the actual number of discrete, extant element occurrences; this uncertainty may be because four EOs have not been confirmed since before 1980. A G2G3 rank implies the species may be imperiled globally because of its rarity (fewer than 100 occurrences), limited distribution or other factors demonstrably making it vulnerable to extinction throughout its range (i.e., endangered throughout its range). *Saussurea weberi* is considered imperiled (S2) by the Wyoming Natural Diversity Database (WYNDD) based on six state Element Occurrence Records (EORs) (two EORs from the Shoshone National Forest in USFS Region 2). It is recognized as a regional endemic with a medium conservation priority (NatureServe 2003, Wyoming Natural Diversity Database 2003a, 2003b). It is considered imperiled (S2) by the Colorado Natural Heritage Program (CNHP), which recognizes 17 element

Table 1. Federal agency management designations for *Saussurea weberi*. Bold type = USFS Region 2 occurrence.

Agency	Region/State	Special management areas with known occurrences	Special status designations
USFS Region 1	Beaverhead-Deerlodge National Forest (Montana)	Anaconda-Pintler Wilderness	sensitive
USFS Region 2	Shoshone National Forest (Wyoming)	Fitzpatrick Wilderness, including proposed Arrow Mountain Research Natural Area and Whiskey Mountain Bighorn Sheep Winter Range Habitat Management Area	none
	Pike National Forest and Arapaho (White River) National Forest (Colorado)	Hoosier Ridge Research Natural Area	
USFS Region 4	Bridger-Teton National Forest (Wyoming) Colorado	Gros Ventre Wilderness and Bridger Wilderness, including Osborne Mountain Research Natural Area	sensitive
BLM	Colorado	Mosquito Pass Area of Critical Environmental Concern	sensitive

occurrence records (14 EORs from Pike National Forest and Arapaho National Forest (administered by White River National Forest) in USFS Region 2) (Colorado Natural Heritage Program 2003b, NatureServe 2003). It is considered critically imperiled (S1) by the Montana Natural Heritage Program (MTNHP) based on one EOR (Montana Natural Heritage Program 2003b, NatureServe 2003).

Saussurea weberi is not included on the Federal Endangered Species List (US Fish and Wildlife Service 1999). *Saussurea weberi* occurs on lands managed by the USDA Forest Service Regions 1, 2, and 4 (Fertig 2000b, Colorado Natural Heritage Program 2003b, Kratz personal communication 2003, Montana Natural Heritage Program 2003a, Wyoming Natural Diversity Database 2003b). In USFS Region 2 it is known from the Shoshone National Forest (Marriott 1988, Fertig et al. 1991, Marriott 1991, Fertig 1992, Fertig 1998, Rosenthal 1999, Fertig 2000a, Fertig 2000b, Welp et al. 2000, Wyoming Natural Diversity Database 2003a, 2003b) and from the Pike and Arapaho national forests (Colorado Natural Heritage Program 2003a, 2003b).

As an alpine species, *Saussurea weberi* occurs in several designated wilderness areas managed by the Forest Service. In Wyoming, all known occurrences are found within designated wilderness areas (Fertig 2000b). In USFS Region 2, it is known from two occurrences in the Fitzpatrick Wilderness on the Shoshone National Forest. One of these two EORs is also located within the Whiskey Mountain Bighorn Sheep Winter Range Habitat Management Area (Wyoming Natural Diversity Database 2003b), while the other is within the proposed Arrow Mountain Research Natural Area (Jones and

Fertig 1999). Elsewhere in USFS Region 2, *S. weberi* is known from a total of 14 occurrences on the Arapaho (administered by White River NF) and Pike national forests. One of the core Colorado populations is located within the Hoosier Ridge RNA, which spans the Pike and Arapaho (administered by White River NF) national forest boundary (USDA Forest Service 1991, Colorado Natural Heritage Program 2003b, Johnston personal communication 2003). In USFS Region 1, *S. weberi* is known from one occurrence on the Anaconda-Pintler Wilderness on the Beaverhead-Deerlodge National Forest (Montana Natural Heritage Program 2003b). In USFS Region 4, it is known from the Bridger and Gros Ventre wilderness areas on the Bridger-Teton National Forest (Wyoming Natural Diversity Database 2003b), and is also known from the Osborne Mountain Research Natural Area (RNA) on the Bridger-Teton National Forest (Fertig and Jones 1994).

No species of *Saussurea* have been federally listed or are currently proposed as candidate species (US Fish and Wildlife Service 1999, 2003).

Existing Regulatory Mechanisms, Management Plans, and Conservation Strategies

Saussurea weberi is not listed as threatened or endangered under the Endangered Species Act (U.S.C. 1531-1536, 1538-1540) and therefore there are no federal laws concerned directly with its conservation. Additionally, it has no formal status within USFS Region 2. Because it is designated a sensitive species in USFS Regions 1 and 4 (**Table 1**), occurrences of *S. weberi* on Forest Service System lands in those

areas may be provided some benefits in terms of inventories, monitoring, and information exchange, as well as special consideration in land use planning and NEPA analysis. The Forest Service does not have a specific management plan or conservation strategy for *S. weberi*. The Hoosier Ridge RNA in Colorado is managed specifically for a suite of rare alpine plant species, including *S. weberi* (USDA Forest Service 1991). However, the legality of the establishment of Hoosier Ridge RNA is currently being challenged due to evidence of prior mining activities across the site (Mountain States Legal Foundation 2003). The Osborne Mountain RNA in Wyoming in USFS Region 4 is also managed for a suite of rare alpine plant species that includes *S. weberi* (Fertig and Jones 1994). The remaining occurrences of *S. weberi* in USFS Regions 1 and 4, in Montana and Wyoming, respectively, may be afforded a higher level of protection by virtue of their remote locations within designated wilderness (e.g., ORVs and other motor vehicles are prohibited). The documentation for the proposed Arrow Mountain RNA on the Shoshone NF includes *S. weberi* as a basis for designation of the RNA. However, the RNA has not yet been established (Jones and Fertig 1999).

As a BLM-listed sensitive species in Colorado, *Saussurea weberi* receives limited benefits in terms of inventories, monitoring, and information exchange, and the species is considered in land use planning, NEPA analysis, and the application of “best practices” (Bureau of Land Management 2001). The BLM does not have a specific management plan or conservation strategy for *S. weberi*. One occurrence of *S. weberi* on BLM-administered land is afforded a higher level of protection by virtue of its location within the Mosquito Pass Area of Critical Environmental Concern (ACEC). The ACEC emphasizes management for threatened, endangered and sensitive plant species, although not *S. weberi* specifically (Bureau of Land Management 1996). The Colorado BLM’s designation of the plant as a sensitive species offers it additional protection, which includes requirements for pre-project surveys in occupied or potential habitat. The combination of BLM state-sensitive species status and location within an ACEC managed for rare plant resources affords *S. weberi* a higher level of management awareness. It is unlikely the BLM would approve actions that might adversely affect the species (Brekke 2003).

Adequacy of current laws and regulations

Saussurea weberi has no specific legal protection that prevents the destruction of individuals or habitat. As of this writing, no conservation strategy has been written

for this species at a state, national or regional level by the Forest Service or any other federal agency. The species has not yet been subjected to many human impacts that have indicated the adequacy of current protection.

Adequacy of current enforcement of laws and regulations

There are no known or reported instances in which an occurrence of *Saussurea weberi* was extirpated as a result of human activities or the failure to enforce any existing regulations. However, this does not necessarily indicate that current regulations or their enforcement are adequate for on-going protection of this species.

Biology and Ecology

Most of the information pertaining to this species is observational as opposed to experimental. Observational information provided the basis for most of the biology, habitat, and life history discussions contained in this assessment.

Classification and description

Saussurea weberi Hultén is a member of the composite family or Asteraceae (Compositae). The Asteraceae is the largest family of dicots and the second largest family of flowering plants (after the Orchidaceae). It includes approximately 1,400 to 1,540 genera and 20,000 to 30,000 species (Walters and Keil 1996). The Asteraceae is included within the order Asterales, subclass Asteridae, and class Magnoliopsida (Dicotyledonae) (Walters and Keil 1996, Interagency Taxonomic Information System 2003, NatureServe 2003). The Asteraceae has a cosmopolitan distribution across an extremely diverse range of habitat conditions, ranging from the polar regions to the tropics, from high alpine settings (as in the case of *S. weberi*) to sea level, from aquatic environments to extremely arid deserts. The Asteraceae includes numerous common cultivated and wild plants, and in many areas of the world its members comprise 10 to 20 percent of the local flora (Walters and Keil 1996). The family includes herbs, shrubs, woody vines, stem-succulents and trees (Bremer 1994, Walters and Keil 1996).

Characters of the specialized inflorescence (the capitulum or head) and flowers (florets) of Asteraceae are defining. The actinomorphic (radially symmetrical) flowers occupying the center of a head in many Asteraceae are termed disk flowers, and are perfect flowers, that is, they form both pollen and seeds. Heads of many Asteraceae have strongly zygomorphic flowers

(termed ray flowers) along the periphery of the head, which are generally either pistillate or neuter, as they typically lack stamens (Walters and Keil 1996). Disk flowers may be borne in heads by themselves, as in the case of *Saussurea* and most other members of the Cardueae tribe, in which case the inflorescence is termed discoid, or referred to as a discoid head. This is generally regarded as a primitive feature (Bremer 1994, Walters and Keil 1996). Systematic studies of Asteraceae also have historically focused on morphological variation across a variety of floral characteristics including the anther, pollen shape and texture, style shape, pappus, and receptacle (Bremer 1994).

Saussurea weberi is in the well-defined, monophyletic tribe Cardueae. The Cardueae are almost all herbaceous, and regarded as a primitive group based on the predominance of discoid heads. They represent one of the oldest herbaceous branches of the Asteraceae, and are thought to have evolved from woody ancestors (Bremer 1994). Members of the Cardueae (approximately 83 genera and 2500 species), include species such as the thistles that are armed with spines as well as the unarmed, closely allied *Saussurea* – *Jurinea* group with more than 500 species worldwide (Bremer 1994).

The holotype for *Saussurea weberi* Hultén is housed at the University of Colorado Museum Herbarium in Boulder, Colorado (University of Colorado Type Specimen Database 2001). That specimen collected by W. Huestis in 1905 was from the summit area of Mt. Lincoln, 14,297 feet, Park County, Colorado. Huestis originally identified the plant as *S. densa* (Hook.) Rydb., but the specimen was then annotated in 1949 by H. D. Harrington and subsequently described by Hultén as a new species (Hultén 1959). Although previously treated as a synonym of *S. densa*, *S. weberi* has been recognized as distinct by Kartesz' Synthesis since 1999 (CNHP 2003c). Treatment of *S. weberi* as a distinct species was also advocated by Scott (1995). Dorn (2001) recognizes only one species of *Saussurea* in Wyoming, *S. weberi*.

In addition to the holotype housed at the University of Colorado Museum Herbarium, (COLO), specimens of *Saussurea weberi* are in collections at the Rocky Mountain Herbarium (RM), Colorado State University Herbarium (CS), and University of Northern Colorado Herbarium (GREE). Since an exhaustive herbarium inventory was not performed as part of this assessment, it's possible that other herbaria may also have specimens of *S. weberi*.

According to Scott (1995), the genus *Saussurea* consists of “perennial herbs with alternate, entire, dentate to sinuate-dentate, or pinnatifid leaves. Heads are solitary, racemose, or corymbose, discoid; involucre imbricate, commonly in 2-4 series; receptacles are flat, with numerous chaffy bracts. Flowers are tubular, perfect, the corollas blue or purple, expanded at the throat. Anthers are caudate; style with a ring of hairs below the branches. Achenes are glabrous, nerved; pappus in two series, the inner plumose, united at the base; the outer of short, rigid, nonplumose bristles.”

Scott (1995) also describes *Saussurea weberi* as a “low, compact, perennial herb with thick stems and alternate, entire, arachnoid-floccose leaves. Upper leaves are sessile or nearly so, the lower ones petiolate, with scattered yellow resinous glands on the lower side. Heads tightly clustered, involucre of 2-3 series of ovate, blunt, imbricate bracts with dark margins and tips. Disk corollas purple. Achenes are glabrous; pappus of inner united plumose bristles and shorter outer, nonplumose bristles”. **Figure 1** and **Figure 2** provide an illustration and close-up photograph of *S. weberi*, respectively.

Hultén (1959) distinguished *Saussurea weberi* from other North American species within the genus on the basis of multiple features, including compact growth form, receptacle bracts, leaf shape and pubescence, and involucre scales. Hultén (1959) noted the most closely related American species was *S. viscida* var. *yukonensis*, known from Alaska, but distinguished *S. weberi* on the basis of its lack of viscid septate hairs on leaf surfaces, longer petioled basal leaves with scattered yellow resinous dots on the lower side, and ovate, broader, and blunter outer involucre scales.

Saussurea weberi is the only species of *Saussurea* known from Wyoming or Colorado (Colorado Natural Heritage Program 2003c, Wyoming Natural Diversity Database 2003a). According to Fertig et al. (1994), similar species include other members of the tribe Cardueae, specifically *Cirsium*, *Carduus*, and *Centaurea* spp., but these genera have leaves, stems, and involucre that are spiny or bristly, features lacking in *Saussurea* (Fertig et al. 1994). In Montana, three species of *Saussurea* are known, *S. americana*, *S. densa*, and *S. weberi* (Watson and Lackschewitz 1980). *Saussurea americana* is distinguished on the basis of its height (stems three to 12 dm tall) and its broad leaves with sharply, evenly toothed margins. *Saussurea weberi*, with stems 0.5 to 2 dm tall and narrow leaves with entire or irregularly toothed margins, is distinguished

Figure 1. Line drawing of *Saussurea weberi* Hultén by Kaye H. Thorne. From Wyoming Rare Plant Guide (Fertig et al. 1994).

from *S. densa* on the basis of phyllary morphology. In *S. weberi* the phyllaries are well imbricate, broad, ovate, and with obtuse apices, whereas *S. densa* is characterized by narrow, scarcely imbricate, lanceolate phyllaries with acuminate or attenuate apices (Watson and Lackschewitz 1980).

Marriott (1988) provides a description of characters useful for field identification of *Saussurea weberi*: “perennial herb to 20 cm in height (generally shorter); leaves lance-shaped averaging 3-5 cm in length, with sparse cobwebby hairs; flower heads tightly clustered, appearing as one large head 2-4 cm across; bracts of flower heads dark-margined; ray flowers none, disc flowers purple; pappus (seed tails)

prominent, feathery, often obscuring the inconspicuous purple disc flowers”.

Distribution and abundance

The Cardueae are thought to be the first major group of the Asteraceae to have dispersed throughout the Northern Hemisphere of the Old World from the South American-Pacific area where the family appears to have originated (Bremer 1994). There are approximately 300 species of *Saussurea* worldwide, with a circumpolar distribution centered in Eurasia, especially Central Asia, and a few species in northwestern North America (Bremer 1994).



Figure 2. Close-up photograph of *Saussurea weberi* by Hollis Marriott. From Fertig 2000b.

Saussurea weberi is a regional endemic with a known global distribution limited to the middle Rocky Mountains extending from central Colorado through southwest Montana, as illustrated in **Figure 3**, **Figure 4**, **Figure 5**, and **Figure 6**. *Saussurea weberi* is endemic to the Rocky Mountains in Colorado, Wyoming, and Montana and occurs within USFS Region 2, as well as within USFS Regions 1 and 4. Within its range, *S. weberi* is disjunct across suitable (e.g., often calcareous) sub-alpine and alpine habitat. It and is known from 24 occurrences in the central Rocky Mountains. Colorado and Wyoming EO distribution and abundance information are summarized in **Table 2** and **Table 3**, respectively. *Saussurea weberi* is known from Colorado in the Mosquito Range and the contiguous Hoosier Ridge in Park and Summit counties (Arapaho and Pike national forests), from west-central Wyoming in the Gros Ventre and Wind River ranges (Bridger-Teton and Shoshone national forests) of Teton, Sublette, and Fremont counties, and from southwest Montana in Deer Lodge and Granite counties (Beaverhead-Deer Lodge National Forest) (O’Kane 1988, Colorado Natural Heritage Program 2003a and 2003b, Montana Natural Heritage Program 2003b, and Wyoming Natural Diversity Database 2003b). While most of the reported occurrences are from Colorado, Wyoming apparently supports the largest overall occurrences in terms of area and number of plants (Wyoming Natural Diversity Database’s EORs 003, 001; Colorado Natural Heritage Program 2003a and 2003b, Wyoming Natural Diversity Database 2003b).

Saussurea weberi is known from 17 reported occurrences in Colorado, 14 of which are on USFS Region 2 national forests. The Pike NF supports nine occurrences (Colorado Natural Heritage Program EORs 001, 002, 004, 008, 010, 014, 019, 021, and 026), including two occurrences that extend onto the adjacent Arapaho NF (EORs 010 and 021) (Colorado Natural Heritage Program 2003a and 2003b). EO 012 occurs on a private mining claim on the Pike National Forest (Colorado Natural Heritage Program 2003d). The Arapaho NF (administered by White River NF) supports seven occurrences (EORs 003, 005, 009, 010, 011, 018, and 021) (Colorado Natural Heritage Program 2003a and 2003b). One occurrence, CNHP EOR 006, is located on land administered by the BLM’s Royal Gorge Field Office in Colorado. This EOR was created by combining several previously reported EORs in close proximity, formerly EORs 022, 023, 024 (Colorado Natural Heritage Program 2003c, 2003d). Portions of this occurrence are located within the 4,036 acre Mosquito Pass Area of Critical Environmental Concern (ACEC), administered by the BLM’s Royal Gorge Field Office (Dawson personal communication 2003). The remaining CNHP EOR 025, is reportedly on private land (Colorado Natural Heritage Program 2003b). A portion of CNHP EOR 003 is located in the Hoosier Ridge RNA, which spans the Pike and Arapaho (administered by White River NF) national forests (USDA Forest Service 1991, Colorado Natural Heritage Program 2003b). It is not certain if all Colorado EORs are extant. On the Pike NF, CNHP EOR 001 hasn’t been

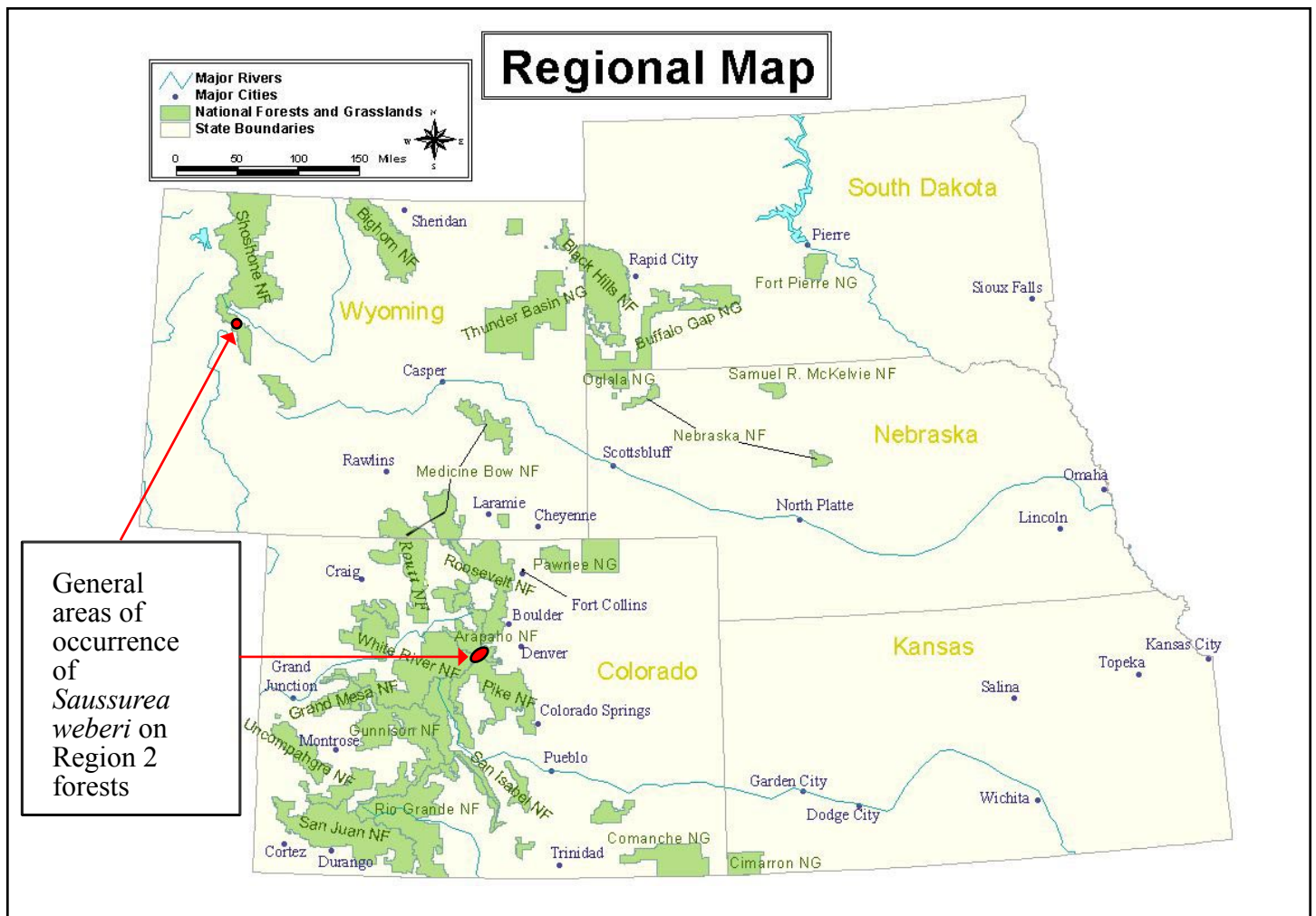


Figure 3. Map of national forest/grassland locations in Region 2 and areas of occurrence of *Saussurea weberi*.

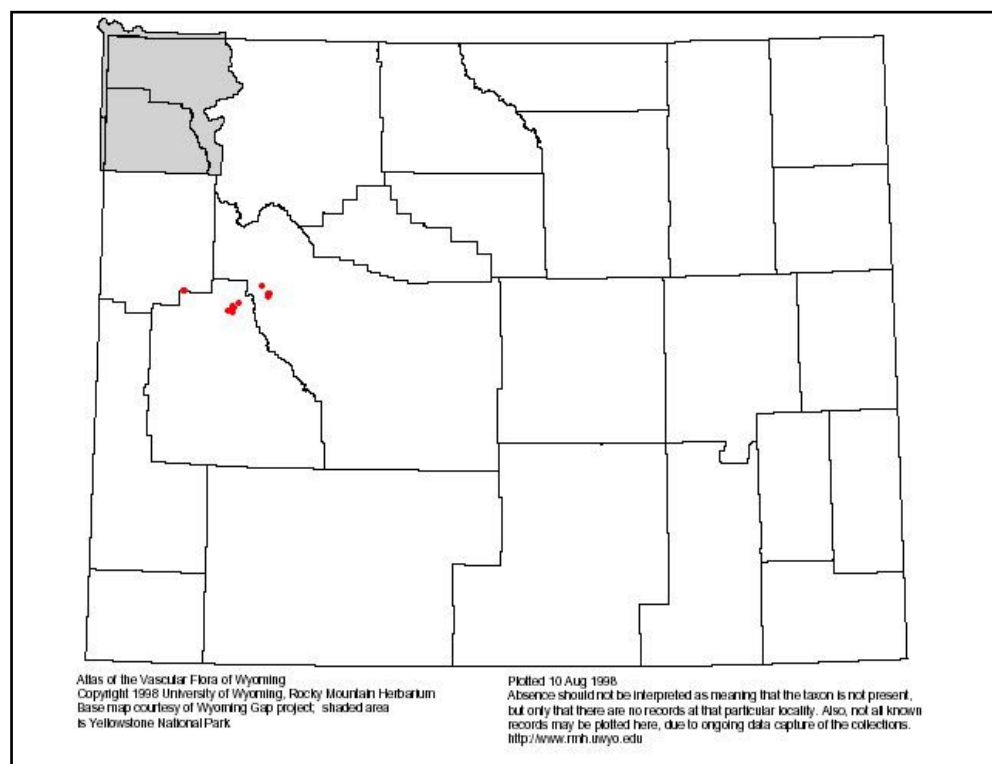


Figure 4. Distribution of *Saussurea weberi* in Wyoming (University of Wyoming 1998)

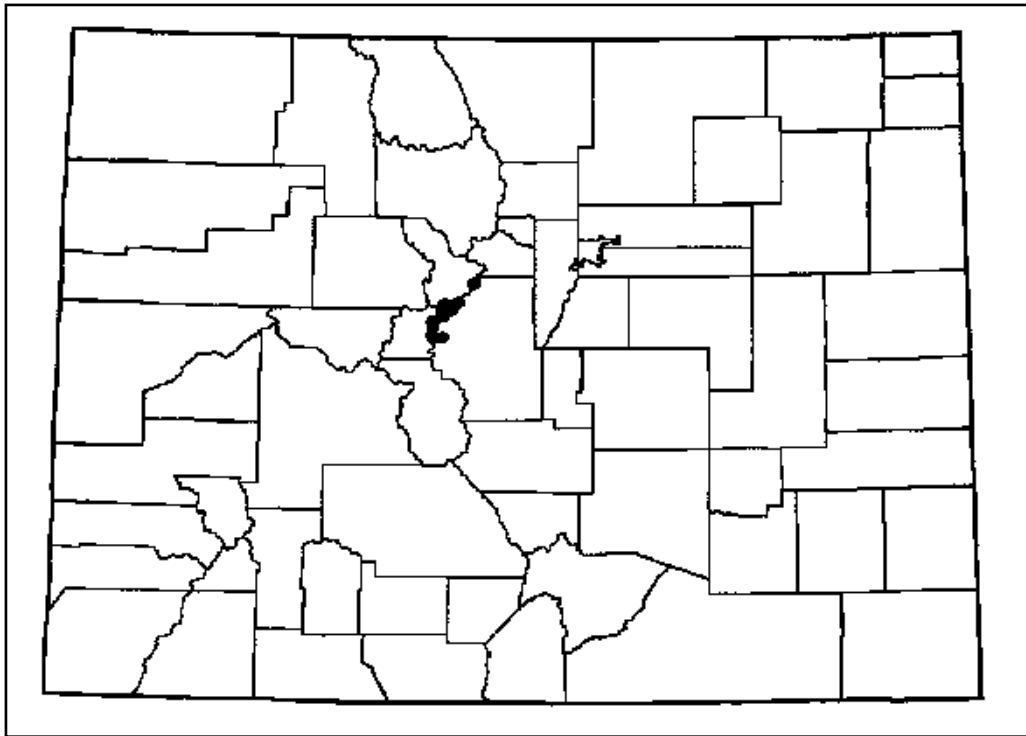


Figure 5. Distribution of *Saussurea weberi* in Colorado (Spackman et al. 1997).

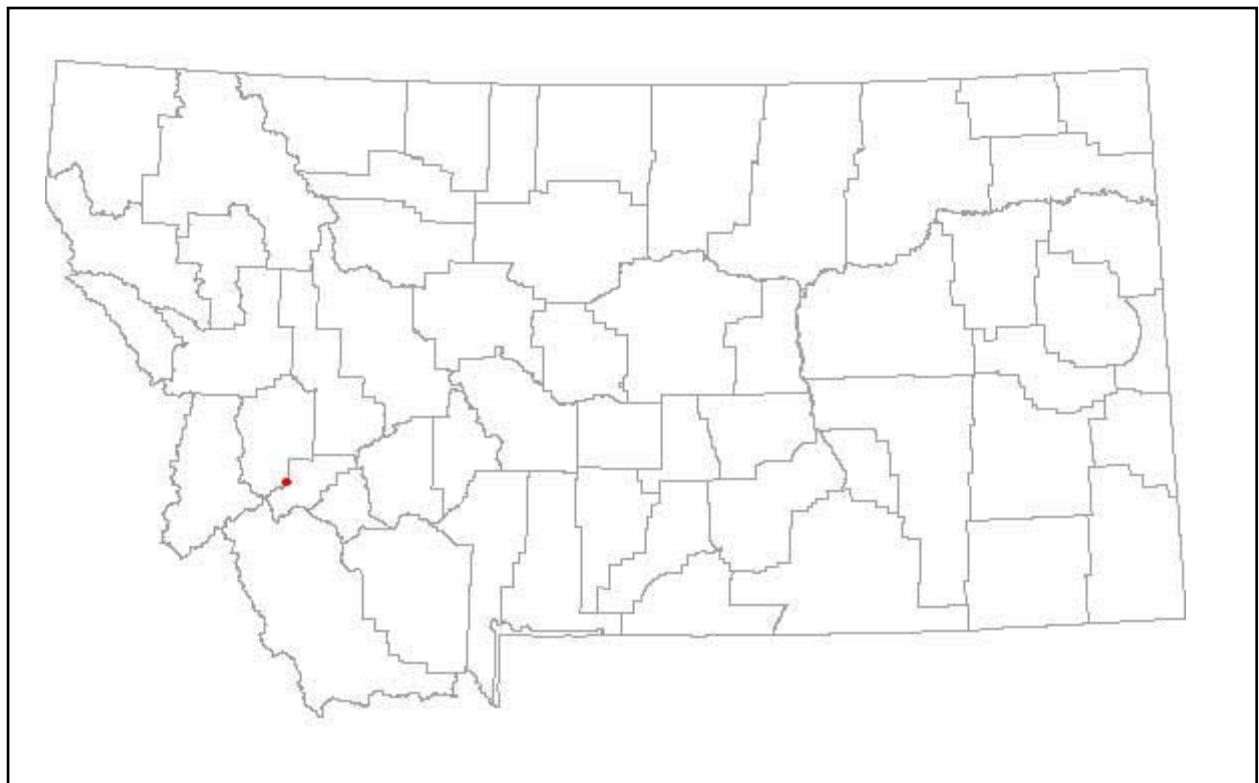


Figure 6. Distribution of *Saussurea weberi* in Montana (Montana Natural Heritage Program 2003a).

Table 2. Selected distribution and abundance information from Colorado Natural Heritage Program Element Occurrence Records (EORs) (Colorado Natural Heritage Program 2003b). Population information is somewhat variable between visits, presumably due to variation in phenology, precise locations visited, different surveyors, etc. Bold type = USFS Region 2 occurrence.

EOR	Ownership	Location	Estimated population size	Estimated population extent in acres	Last observed	Threats
001	Pike National Forest	Cameron Amphitheater	two suboccurrences: 90 to 140 plants, 70 to 500 plants	two suboccurrences: 2 and 10 acres	1989	overall in good condition; potential for renewed mining and 4WD activity
002	Pike National Forest	Mount Sheridan	18 to 2,200 plants; several previously reported suboccurrences not relocated	unknown	1989	renewed mining and ORVs
003	Arapaho National Forest (administered by White River National Forest)	Hoosier Ridge (Hoosier Ridge Research Natural Area)	<50 to 350 plants	<1/4 to 24	1994	hiking – low activity; natural – slight from gopher activity and unstable soil
004	Pike National Forest	Teller Mountain	unknown	unknown	1980, not relocated in 1989 survey	near abandoned mine – potential mining activities, ORV and 4WD activities, hiking
005	Arapaho National Forest (administered by White River National Forest)	Blue Lakes	5 to 16 plants	small, <1 to 2 acres	1996	unknown
006	BLM	Mosquito Range	4 to 250 plants	four small occurrences in one+ acres; this EO created by CNHP by combining former EOs 22, 23, 24	1998	ORV and 4WD activities in vicinity, hiking, foot traffic
008	Pike National Forest	Mosquito Range	a few to several hundreds of plants	25 to 30	1998	likely no current threats – long-abandoned small exploratory mine and several small test pits on slope
009	Arapaho National Forest (administered by White River National Forest)	Mosquito Range	unknown	unknown	1948	unknown
010	Arapaho National Forest (administered by White River National Forest), Pike National Forest	Boreas Pass	unknown	unknown	1948	unknown
011	Arapaho National Forest (administered by White River National Forest)	North Star Mountain	300 to 350 plants in 2000; 100 plants in 1997; 100 plants in 1994; 2 plants in 1990; 0 plants in 1989	30 by 40 feet	2000	renewed mining, road erosion into nearby willow habitat; 4WD/ORV use in vicinity
012	private	Dolly Varden	2 plants in 1990; 86 to 4,500 plants in 1989 by same surveyor as in 1990	30 to 33	1990	potential for renewed mining, 4WD activity – but less potential than other portions of Mt. Bross, gopher activity
014	Pike National Forest	Teller Mountain	8 plants	unknown	1992	inactive mining sites nearby
018	Arapaho National Forest – White River National Forest	Mosquito Range	unknown	unknown	1991	unknown

Table 2 (concluded).

EOR	Ownership	Location	Estimated population size	Estimated population extent in acres	Last observed	Threats
019	Pike National Forest	Mount Sheridan (Horseshoe Cirque)	>1,000 plants in 2000; >6 plants in 1989; occasional in 1986; common in 1985	2	2000	plants in road and along roadside, 4WD/ORV use and renewed mining activity
021	Arapaho National Forest (administered by White River National Forest), Pike National Forest	North Star Mountain	unknown	unknown	1994	population threatened
022, 023, 024	BLM	see EOR 006	combined with EO 006	see EOR 006	see EOR 006	see EOR 006
025	private	Mosquito Range	59 to 250 plants	unknown	1989	potential threat of erosion from increased foot traffic due to hiking and fishing on site
026	Pike National Forest	Weston Pass	100	unknown	2000	unknown

Table 3. Selected distribution and abundance information from Wyoming Natural Diversity Database Element Occurrence Records (EORs) (Wyoming Natural Diversity Database 2003b). Bold type = USFS Region 2 occurrence.

EOR	Ownership	Location	Estimated population size	Estimated population extent in acres	Last observed	Threats
001	Shoshone National Forest, Fitzpatrick Wilderness Area, proposed Arrow Mountain RNA	Arrow Mountain, Wind River Range	several sub-occurrences, collectively estimated at several thousand plants	740	1998	low
002	Shoshone National Forest, Fitzpatrick Wilderness Area, Whiskey Mountain Bighorn Sheep Winter Range Habitat Management Area	Southeast flank of Whiskey Mountain, Wind River Range	unknown	4	1984	unknown
003	Bridger-Teton National Forest, Bridger Wilderness	Big Sheep Mountain, former EO 005 combined with this occurrence	approximately 10,100 to >16,000 plants, with most extensive sub-colony on west slopes	115	1994	minimal, low recreation use, no grazing
006	Bridger-Teton National Forest, Bridger Wilderness	Gypsum Mountain	approximately 1,100 to >1,600 plants; 4 sub-occurrences, locally abundant	10	1994	well protected by rugged and poorly accessible location
007	Bridger-Teton National Forest, Bridger Wilderness, Osborne Mountain Research Natural Area	Green River Lake/Osborne Mountain	500 plants	5	1993	none noted but small habitat area
008	Bridger-Teton National Forest, Gros Ventre Wilderness	Darwin Peak, Gros Ventre Range	unknown	scattered over much of the higher ridges and tops	1994	unknown

revisited since 1990, while 004 was originally found in 1980, but not relocated during a 1989 follow-up survey (Colorado Natural Heritage Program 2003a and 2003b). On the Arapaho NF, CNHP EORs 009 and 010 haven't been relocated since they were first observed in 1948 (Colorado Natural Heritage Program 2003a and 2003b). All other CNHP EORs (001, 002, 003, 004, 005, 008, 011, 014, 018, 019, 021, and 026) on USFS Region 2 national forests have been discovered or relocated since 1990 and are presumed to be extant (Colorado Natural Heritage Program 2003a and 2003b). None of the remaining three CNHP EORs on BLM or private lands has been revisited since 1990.

Population sizes are reported for 12 of the 17 Colorado EORs, with totals varying from two to several hundred individuals in 10 of the occurrences. The largest reported occurrences are CNHP EOR 012, the Dolly Varden Gulch site, containing approximately 4,500 individuals on private land, and CNHP EOR 019, the Mount Sheridan site on the Pike NF containing approximately 1,000 individuals (Colorado Natural Heritage Program 2003a and 2003b). For CNHP EORs that have been visited more than once, the reported population sizes appear to vary considerably over time. For example, at CNHP EOR 011, on the Arapaho NF, only two plants were noted during surveys in 1990, but 300 to 350 plants were observed during 2000 (Colorado Natural Heritage Program 2003a and 2003b). This may be due to a number of reasons, including population variability through time, variability in survey area boundaries and surveyors, and variability in phenology at survey time from year to year. Numerous entries on CNHP records note rhizomatous reproduction as an important mode of reproduction, which appears to be accurate based on recent examinations of herbarium specimens provided by Abbott (personal communication 2004). However, *Saussurea weberi* has previously not been widely recognized as a rhizomatous species (see discussion under Reproduction Biology) (Colorado Natural Heritage Program 2003a and 2003b).

In Wyoming, *Saussurea weberi* is known from six EORs, all of which are presumed extant. Two of the Wyoming EORs are on the Shoshone National Forest (USFS Region 2). The remaining four WYNDD EORs for *S. weberi* are for occurrences on the Bridger-Teton National Forest (USFS Region 4, Fertig 2000b, Wyoming Natural Diversity Database 2003b). Both of the Shoshone NF occurrences (WYNDD EORs 001 and 002) are in the Fitzpatrick Wilderness area (Wyoming Natural Diversity Database 2003b). WYNDD EOR 001 was first observed in 1988, last observed in 1996, and has been estimated to include several thousand

individuals. WYNDD EOR 001 is also within the proposed Arrow Mountain Research Natural Area (RNA) and *S. weberi* is one of the species cited as a basis for designation of the RNA (Jones and Fertig 1999, Wyoming Natural Diversity Database 2003b). WYNDD EOR 002 has only been observed in 1984 and no population estimate was reported (Wyoming Natural Diversity Database 2003b). The four EORs that occur on the Bridger-Teton NF are also within designated wilderness areas; three are in the Bridger Wilderness (WYNDD EORs 003, 006, and 007; the latter is also located in the Osborne Mountain RNA) and one is in the Gros Ventre Wilderness (WYNDD EOR 008) (WYNDD 2003b). The Bridger-Teton NF may contain the greatest number of individuals known for this species, with a total of more than 22,500 plants in the four EORs (Wyoming Natural Diversity Database 2003b).

In Montana, one occurrence has been reported, disjunct from the west-central Wyoming occurrences (Watson and Lackschewitz 1980, Montana Natural Heritage Program 2003b). The Montana occurrence is located approximately ½ mile southwest of Mt. Tiny in the Goat Flat area of the Anaconda-Pintlar Mountains, Deerlodge County, Montana (Watson and Lackschewitz 1980, Achuff and Roe 1992). This population was first observed in 1973 and last observed in 1978, and was estimated to contain 500 to 1,000 individuals over approximately 7.7 acres (Achuff and Roe 1992). An attempt to relocate the occurrence in 1991 was unsuccessful (Achuff and Roe 1992). It is not clear how much additional potential habitat remains in Montana.

In Colorado, additional habitat may exist in the Sawatch Mountains on the Gunnison National Forest and other alpine areas with exposed limestone and dolomite (Johnston personal communication 2003) and portions of the San Juan Mountains. According to Johnston, maybe as little as 50 percent of the potential habitat has been surveyed and there is a reasonably high likelihood that undocumented populations of *Saussurea weberi* exist (Johnston personal communication 2003). In Wyoming, Marriott (1988) reported that all potential habitat on the Shoshone National Forest and in the Wind River Range on the Bridger-Teton National Forest had been surveyed. *Saussurea weberi* is not known or expected from the Absaroka or Beartooth portions of the Shoshone National Forest, which are primarily composed of volcanic material (Scott personal communication 2003). Scott (personal communication 2003) noted there is only one likely area of alpine limestone habitat in the Absaroka Range, a lens of limestone near the southern end of the range near the

hydrologic divide between the head of the East Fork of the Wind River and Wood River. Additional potential habitat may also be present along the southern end of the Wind River Range where limestone outcrops extend into alpine and sub-alpine areas as low as approximately 9,500 feet (Scott personal communication 2003).

Occurrences may be small and sparse to locally abundant, depending on the suitability of habitat. Population size estimates are reported for some EORs and range from as few as two individuals to as many as 15,000 plants (Colorado Natural Heritage Program 2003b, Wyoming Natural Diversity Database 2003b). The largest known occurrences (WYNDD EORs 003 and 006) are located in wilderness areas on USFS Region 4's Bridger-Teton NF and consist of locally abundant colonies containing between 11,200 and 17,600 individuals spread over 115 acres (Wyoming Natural Diversity Database 2003b). The largest occurrence on the Shoshone NF (WYNDD EOR 001) is estimated to contain several thousand individuals over approximately 740 acres (Wyoming Natural Diversity Database 2003b).

The total number of individual *Saussurea weberi* plants in Colorado (based on 12 EORs that include numerical estimates of population size) may be greater than 8,000 (Colorado Natural Heritage Program 2003b). The remaining five CNHP EORs did not include population size estimates (Colorado Natural Heritage Program 2003b). The total number of individual *S. weberi* plants in Wyoming (based on four EORs that include numerical estimates of population size) is estimated to range from 19,500 to greater than 25,500 (Wyoming Natural Diversity Database 2003b). The remaining two WYNDD EORs did not include population size estimates (Wyoming Natural Diversity Database 2003b).

There is no information regarding historical distribution and abundance, other than what can be gleaned from the CNHP, MTNHP, and WYNDD EORs and other WYNDD reports. The CNHP records suggest there is considerable variability in population size estimates between resurveys for individual sites (Colorado Natural Heritage Program 2003b). Although there are no documented instances of loss of *Saussurea weberi* populations or habitat, many of the Colorado EOs are reportedly in the immediate vicinity of historic mining activities and one occurrence on the Pike NF (CNHP EOR 019) occurs along a road, which may suggest some compatibility with disturbance (Colorado Natural Heritage Program 2003b). In general however, *S. weberi* does not appear to be a disturbance-adapted

species, as shown by its apparent association with stable alpine vegetation (Johnston personal communication 2003). The inference is that *S. weberi* may not tolerate frequent or intense disturbance (Johnston personal communication 2003). Nearly all of the available information suggests the range, habitat availability, or occurrence numbers of *S. weberi* have not decreased, perhaps because of the remote and rugged locations of its alpine habitat. However, some Colorado EORs are in areas that may have been adversely impacted by previous mining activities.

It is unclear if, or how, past human activities have altered the distribution and abundance of *Saussurea weberi*. It is also unclear how past natural events have altered the distribution and abundance of the species, but it is likely the species' distribution was more widespread and occurred at lower elevations during previous cold and wet periods such as the Pleistocene, when more suitable habitat may have been available. *Saussurea weberi* occurs across a fairly broad area of the central Rocky Mountains. Extant occurrences are widely scattered and discontinuous habitat contributes to isolation between the disjunct occurrences. Other occurrences of *S. weberi* may exist since comprehensive surveys of potential habitat have not been completed across its range.

The Colorado occurrences represent the most southerly occurrence of any *Saussurea* species in North America. Isolation between occurrences is relatively extreme across the species' range, as the three major population centers are disjunct from one another by several hundred miles. However, in Colorado and Wyoming, occurrences are fairly tightly clustered within high elevation zones and there is a potential for some transfer of genetic material between occurrences within each cluster. The Montana occurrence appears to be the most isolated.

Population trend

There are no published data on population trends. The Colorado EORs reveal considerable variation in year to year tallies of individuals for particular sites, suggesting that year to year population variability may be high (Colorado Natural Heritage Program 2003b). However, detailed, specific entries are not available for all of the CNHP EORs (Colorado Natural Heritage Program 2003b). In Wyoming, occurrences are assumed to be stable (Fertig 2000b, Wyoming Natural Diversity Database 2003b), although evidence is limited to available EORs and summary reports authored by WYNDD for various land management

agencies. Wyoming occurrences may have over ten thousand individuals, but are restricted to small areas of suitable alpine habitat (Fertig 200b). In Montana, the only known occurrence hasn't been relocated since 1978, and it is unclear if it is extant (Montana Natural Heritage Program 2003b).

While published monitoring data are lacking, several CNHP EORs noted that reproduction was good, primarily due to rhizomatous spreading (see discussion under Reproductive Biology and Autecology) (Colorado Natural Heritage Program 2003b).

Abbott is presently conducting the ninth year of a planned 10-year study on patterns of *Saussurea weberi* shoot production in the Horseshoe Cirque, Colorado occurrence (CNHP EO 019) (Abbott personal communication 2004). The sample consists of fifty two permanently-marked, circular, one meter-square quadrats, originally established for a pollination study (Abbott 1998). The quadrats were centered on existing shoot clusters and have been surveyed annually. Annual data collection has included a count of floral shoots and vegetative shoots, which are tallied into three arbitrary size classes based upon the number of leaves. Although not directly indicative of plant density since the quadrats were initially centered on existing plants, the study offers insights into the overall stability of the Horseshoe Cirque occurrence over time, longevity of individual plants (assuming many of the shoots in a particular quadrat are from developed caudices, which is thought to be the case, but not known for certain), relative abundance of reproductive versus vegetative shoots, and vigor of plants in individual quadrats over time. According to Abbott, (personal communication 2004), *S. weberi* overwhelmingly presents itself in vegetative condition in the field and oftentimes what appears in the field to be a single shoot is actually a tight cluster of five, seven or more shoots. Over the course of the study, the total number of shoots growing each year within the 52 study quadrats has varied from about 1,300 to 1,600, with an apparent mean of around 1,500. It is unclear whether these fluctuations represent recruitment events of new genetic individuals from seed or an increase in vegetative shoots, or a decline in shoot production in response to environmental stressors such as drought. The number of floral shoots as a percentage of the total each year has varied from about 2 to 16 percent. The percentage of floral shoots has unerringly alternated high then low over the years of the study, with the apparent mean low around 4 percent and the apparent mean high around 14 percent; 2004 is predicted to be a high production year. The year of highest percent floral shoot production was 2000,

while the year of lowest percent production was 2003. Since the start of the study, *S. weberi* has definitely become extirpated in only one quadrat; the plants in that quadrat underwent an unexplained precipitous decline over three years, with no plants present since 1999. Shoots in two other quadrats were completely buried by northern pocket gophers and produced no shoots in 2003, but it's possible some shoots may still emerge in 2004. *Saussurea weberi* shoots within other quadrats have been in noticeable slow decline for years, but still persist in low numbers. The quadrats that consistently have produced the greatest total number of shoots and flowers are those sited on bare mine rubble and among large rocks at the edge of inactive patterned ground; this may emphasize the nature of *S. weberi* as a stress-tolerant species capable of persisting within a range of plant communities, but which does best in the absence of competition.

Much of the existing and potential habitat on the Shoshone, Arapaho (administered by White River NF) and Pike national forests remains mostly intact, largely as a result of its remote and rugged nature (Houston personal communication 2003, Johnston personal communication 2003). This is especially true for Wyoming occurrences that are located in a designated wilderness area and for a portion of the Colorado occurrence located within the Hoosier Ridge RNA.

Although there are no other hard data regarding population stability over time at any scale, there does not appear to be an overall decline of the species' available habitat, so it may be reasonable to infer that overall population numbers are relatively stable. Similarly, there is no information available to suggest that any of the individual occurrences have declined or are at any immediate risk of declining. In Wyoming, occurrences are assumed to be stable (Wyoming Natural Diversity Database 2003a). Based on the apparently limited loss of habitat to date, and in the absence of monitoring data, there is no reason to suspect an overall or specific decline in habitat availability or population size for *Saussurea weberi* at present.

There are substantial geographic and habitat barriers between clusters of occurrences. Collection of additional long-term monitoring data across multiple occurrences is necessary to definitively characterize population stability and trend for this species

Habitat

Saussurea weberi's habitat is discontinuous on the landscape and its geographic range is limited

(Scott 1995, Wyoming Natural Diversity Database 2003b). Throughout its range, *S. weberi* occurs in high elevation, subalpine to alpine sites, on rocky, exposed limestone slopes, talus, and ridges (Scott 1995). In Colorado, *S. weberi* occurs on gravelly tundra slopes amid scree, often on solifluction lobes on exposed sites with poorly developed soils derived from Leadville limestone and Manitou dolomite (O’Kane 1988). The Colorado occurrences range from 10,400 to 14,300 feet in elevation (O’Kane 1988, Colorado Natural Heritage Program 2003b). In Wyoming, *S. weberi* occurs on alpine talus slopes, mostly on limestone-derived substrates between 9,600 and 11,500 feet (Fertig 1998, Fertig 2000b, Wyoming Natural Diversity Database 2003b). In Montana, it occurs between 9,300 and 9,500 feet in moderately dry alpine meadows and adjacent slopes on northwest aspects, in well-developed, calcareous soils derived from the Newland Limestone Formation (Watson and Lackshewitz 1980, Montana Natural Heritage Program 2003b).

The alpine landscape of the Middle Rocky Mountains has been shaped by a long series of geologic events as well as by glaciation during the Pleistocene (Scott 1995). Since the Pleistocene, processes such as nivation, solifluction, and frost action have continued to shape alpine landscapes and affect habitat suitability for a variety of plant species (Scott 1995).

The alpine zone is characterized by severe environmental conditions, and microhabitats play an important role in defining the distribution of many plant species (Scott 1995). Relatively small changes in slope and exposure can result in major microclimatic differences. The alpine environment is generally characterized by low temperatures during winter and summer, high wind speed, and intense sunlight, since atmospheric absorption of light radiation is reduced at higher elevations (Scott 1995). During the summer months in the Wind River Range for instance, the high elevation and clear air provide alpine zones with the maximum photoperiod for photosynthesis (Scott 1995). Temperatures are typically much higher near the ground surface, with generally moderate daily air temperatures within the 10 cm above the ground that constitute the alpine plant growth zone (Scott 1995). Freezing temperatures often occur at night, even during the summer growing season (Scott 1995). Wind speeds are often very high in alpine habitats, affecting plant physiological processes such as water and heat retention, and ultimately energy assimilation, plant growth, and reproduction (Scott 1995). As Scott (1995) notes, wind also affects important environmental variables such as “distribution and depth of snow cover, resulting in a

mosaic of growing seasons and conditions reflected in community patterns, composition, and appearance”.

Selected habitat information for Colorado and Wyoming EORs is presented in **Table 4** and **Table 5**, respectively. In Colorado, *Saussurea weberi* reportedly occurs on exposed sites with poorly developed soils derived from Leadville limestone and Manitou dolomite, as well as on alpine solifluction lobes, gravelly tundra slopes, and scree (Colorado Natural Heritage Program 2003c). An anonymous peer reviewer of this document noted that while the related *S. densa* prefers unstable screes, *S. weberi* occurs on stable tundra. Of the 17 CNHP EORs, five are reported to occur on soils derived from either limestone or dolomite (CNHP EORs 002, 008, 012, 019, 026), one on rocky entisols (CNHP EOR 001), three on steep tundra slopes between talus slides (CNHP EOR 003, 009, 010), one in the bottom of a steep, willow-covered gully (CNHP EOR 004), one on a gneiss bench with peaty soils (CNHP EOR 005), one on a rocky slope (CNHP EOR 006), one in organic soils on a rocky slope (CNHP EOR 022), one in an alpine wetland with *Salix brachycarpa* (CNHP EOR 021), and three with no substrate data (CNHP EOR 011, 014, 018).

Most of the Colorado occurrences are on solifluction lobes, characterized by well-vegetated, successional stable sites, with individual *Saussurea weberi* plants typically one to three feet apart from one another and interspersed with other species (Johnston personal communication 2003).

In Wyoming, *Saussurea weberi* habitat has been variously described as alpine cushion plant communities on gentle slopes and summit ridges, on semi-bare, dry, calcareous sandy-clay shale soil with brownish sandstone colluvium on the surface, vegetation cover 20 to 25 percent (**Figure 7**); pockets of semi-bare soil on steep talus slopes above outcrops of reddish, slate-like limey sandstone, vegetation cover extremely low; and openings among low mats of *Betula glandulosa* and *Salix glauca* on dry, loamy soils with well-developed moss layer and scattered quartz gravel (WYNDD EOR 001); east, west and south-facing alpine limestone and sandstone talus slopes in pockets of pinkish or tan sandy soil with limey gravel and usually well-developed cryptogam crusts, vegetative cover low; cushion plant communities on alpine flats on “stone pavement” (consisting of smoothed stones with narrow soil gaps between them); understory of Engelmann spruce woods on west-facing slopes just below timberline on fine-textured sandstone and shale with scattered sandstone rocks and boulders. At

Table 4. Selected habitat information from Colorado Natural Heritage Program Occurrence Records (EORs) (Colorado Natural Heritage Program 2003b). Bold type = USFS Region 2 occurrence. CNHP Occurrence Rank definitions: The A to D scores assigned for CNHP ranks are approximate cumulative summaries (i.e., excellent, good, fair, poor respectively) of quality, condition, and sustainability of the population and its habitat. Ranks are assigned only for those occurrences where the species has been surveyed. Ranks are assigned by botanists with species and landscape familiarity, although no defined rank standards have been developed and reviewed specifically for *Saussurea weberi*. An “E” rank indicates an occurrence is extant.

EOR	Ownership	Location	Elevation (ft)	CNHP Rank	Landform - Soil	Aspect	Vegetation cover	Habitat condition
001	Pike National Forest	Cameron Amphitheater	12,800 to 13,000	A	Rocky entisol slope, 15 to 20 degree and 25 to 30 degree slopes	northeast, southeast	tundra – <i>Kobresia myosuroides</i> , <i>Ipomopsis globularis</i> , <i>Acomastylis rossii</i> , <i>Carex</i> spp.	vegetation and habitat in good overall condition, site is wet most of year, moderate manmade disturbance from erosion of road cut immediately adjacent to a few plants
002	Pike National Forest	Mount Sheridan	12,800 to 13,790	not rated	Manitou dolomite, cobbly, gravelly loam 10 degree slope	southeast	common on uppermost vegetated slopes	unknown
003	Arapaho National Forest (administered by White River National Forest)	Hoosier Ridge (Hoosier Ridge Research Natural Area)	12,080 to 12,640	B (A if higher population estimates are accurate)	glaciated mountain slopes and ridges, along stable rock stripes, 15% slope, entisol	northwest	tundra – steep tundra slope between talus slides, dry-moist meadow, 60 to 70 % forb, 30-40% graminoid, <5% total bare ground	good - fair
004	Pike National Forest	Teller Mountain	11,900	unknown	bottom of steep willow-covered gully	unknown	in grassy openings and low willow patches	unknown
005	Arapaho National Forest (administered by White River National Forest)	Blue Lakes	11,720	C – small population	Gneiss benches, peaty slope, 20 to 25 degrees	west-northwest	graminoid, willow	unknown
006	BLM	Mosquito Range	12,240 to 12,880	C	rocky soil, 0 to 40%, 15 to 20 degree slopes	north, east	rather closed vegetation and little disturbed; graminoid, forb, willow	excellent to good condition

Table 4 (cont.).

EOR	Ownership	Location	Elevation (ft)	CNHP Rank	Landform - Soil	Aspect	Vegetation cover	Habitat condition
008	Pike National Forest	Mosquito Range	12,100 to 12,500	unknown	Glaciated slopes, Leadville dolomite and dolomitic limestone, Manitou dolomite. Midslope, 15 to 20% slope, rocky soil, loose talus	northeast	tundra vegetated patches on <i>Dryas</i> stabilized scree slope, shrub 0 to 5%, forb 10%, graminoid 0 to 40%, moss/lichen 0 to 30%, total bare ground < 90%	unknown
009	Arapaho National Forest (administered by White River National Forest)	Mosquito Range	12,400	- none - last observed more than 20 years ago	steep tundra slope between talus slides	north	unknown	unknown
010	Arapaho National Forest (administered by White River National Forest), Pike National Forest	Boreas Pass	12,400	-none - last observed more than 20 years	steep tundra slope between talus slides	north	unknown	unknown
011	Arapaho National Forest (administered by White River National Forest)	North Star Mountain	11,960 to 12,000	C	unknown	unknown	willow, forb	actual site relatively undisturbed
012	private	Dolly Varden	12,120 to 13,240	B+	Manitou dolomite, rocky entisol, rocky loam	east, northeast	willow, forb, graminoid	slight natural and manmade disturbance – old mining activity
014	Pike National Forest	Teller Mountain	11,800	unknown	unknown	unknown	unknown	fair to poor

Table 4 (concluded).

EOB	Ownership	Location	Elevation (ft)	CNHP Rank	Landform - Soil	Aspect	Vegetation cover	Habitat condition
018	Arapaho National Forest (administered by White River National Forest)	Mosquito Range	12,000	unknown	alpine community	unknown	alpine community	unknown
019	Pike National Forest	Mount Sheridan (Horse-shoe Cirque)	12,275 to 12,300	A	Limestone, rocky, alpine fellfields and wetlands, 0 to 30 degree slope	all	uppermost vegetated slopes, forb, graminoid, and willow	A large occurrence covering a fairly large area and elevation range; although some plants are found along road, many are also in natural settings, with no non-native species. Area fragmented by mining roads in some places, surrounding high quality landscape is extensive (in 2000); relatively small amount of fair to poor quality habitat on site with moderate to heavy mining road related disturbance (1989)
021	Arapaho National Forest (administered by White River National Forest), Pike National Forest	North Star Mountain	12,000	unknown	unknown	unknown	alpine wetland below mine tailings with water source	unknown
022, 023, 024	BLM	see EOR 006	see EOR 006	see EOR 006	see EOR 006	see EOR 006	see EOR 006	see EOR 006
025	private	Mosquito Range	12,240 to 12,740	unknown	rock striping, 0 to 30 degree rocky slope	north, east	graminoid, forb	excellent to good
026	Pike National Forest	Weston Pass	11,900 to 12,000	BC	Leadville limestone, alpine tundra and talus	unknown	forb, graminoid	no plants in natural habitat, only plants found growing around old mining holes

Table 5. Selected habitat information from Wyoming Natural Diversity Database Element Occurrence Records (EORs). Bold type = USFS Region 2 occurrence. WYNDD Occurrence Rank definitions: The A to D scores assigned for WYNDD ranks are approximate cumulative summaries (i.e., excellent, good, fair, poor; respectively) of quality, condition, and sustainability of the population and its habitat. Ranks are assigned only for those occurrences where the species has been surveyed. Ranks are assigned by botanists with species and landscape familiarity, although no defined rank standards have been developed and reviewed specifically for *Saussurea weberi*. An “E” rank indicates an occurrence is extant.

EOR	Ownership	Location	Elevation (ft)	WYNDD Rank	Landform - Soil	Aspect	Vegetation cover	Habitat condition
001	Shoshone National Forest, Fitzpatrick Wilderness Area, proposed Arrow Mountain Research Natural Area	Arrow Mountain, Wind River Range	12,000 to 11,500	A	summit of Arrow Mountain and Mount 11016. 1) gentle slopes and summit ridges on semi-bare dry calcareous sandy-clay shale soil with brownish colluvium on the surface; 2) semi-bare soil on steep talus slopes above outcrops of reddish, slate-like limy sandstone; and 3) dry loamy soils with well-developed moss layer and scattered quartz gravel	south, southwest	1) alpine cushion plant communities, 20 to 25% cover; 2) extremely low cover; and 3) openings along low mats of shrubby birch and willow	very good
002	Shoshone National Forest, Fitzpatrick Wilderness Area, Whiskey Mountain Bighorn Sheep Habitat Management Unit	Southeast flank of Whiskey Mountain, Wind River Range	11,150	unknown	exposed slopes in alpine zone	east	unknown	unknown
003	Bridger-Teton National Forest, Bridger Wilderness	Big Sheep Mountain, former EO 005 combined with this occurrence	10,700 to 11,500	unknown	mountain summit flats, rim, and slopes; 1) limestone and sandstone talus slopes in pockets of pinkish soil with limy gravel; alpine flats on stone pavement; and 3) fine textured sandstone and shale with scattered sandstone rocks and boulders	east, west, south	1) usually well-developed cryptogamic crusts; 2) cushion plant communities; and 3) understory of Engelmann spruce woods just below timberline	excellent
006	Bridger-Teton National Forest, Bridger Wilderness	Gypsum Mountain	10,600 to 11,000	AB	alpine talus slopes on sandy pinkish soil patches among boulders below cliffs of sandstone and limestone	west	alpine forb	unknown
007	Bridger-Teton National Forest, Bridger Wilderness, Osborne Mountain Research Natural Area	Green River Lake/Osborne Mountain	10,800 to 11,000	AB	Madison formation, bare limestone talus slope below summit ridge and krummholz zone; pockets of soil among talus	west	sparse, low alpine forbs	pristine
008	Bridger-Teton National Forest, Gros Ventre Wilderness	Darwin Peak, Gros Ventre Range	9,600 to 11,647	E	rocky alpine slopes	east, southeast	alpine forb	unknown



Figure 7. Habitat of *Saussurea weberi* by C. Refsdal (Fertig et al. 1994).

timberline, these spruces become stunted krummholz (WYNDD EOR 003); exposed east-facing slope in alpine zone (WYNDD EOR 002); alpine talus slopes on sandy pinkish soil patches among boulder cliffs of sandstone and limestone (WYNDD EOR 006); west-facing bare limestone talus (Madison Formation) slope below summit ridge and below Engelmann spruce krummholz zone, mostly restricted to pockets of soil among talus, sparsely vegetated with low alpine forbs (WYNDD EOR 007, Wyoming Natural Diversity Database 2003b). *Saussurea weberi* is absent from adjacent granitic slopes and ridges and is largely absent from dense turf mats dominated by *Geum rossii*.

A summary of climate data for a reporting station within five miles of known *Saussurea weberi* occurrences in Colorado indicates a climate characterized by cold winters and cool summers. Precipitation is relatively uniform throughout the year, and average maximum snow depth is approximately 50 inches by the end of the maximum accumulation period in mid- to late April (Western Regional Climate Center 2003). The Climax, Colorado climate station (Number 051660, elevation 11,500 feet) is in the general vicinity of the Colorado occurrences, although toward the lower end of the species' elevation range. Data from this

station indicate that the average annual precipitation is 23.06 inches; average monthly temperatures range from approximately 13 degrees (January) to 52.0 degrees Fahrenheit (July). Monthly precipitation is relatively uniform throughout the year with averages for the growing season being: May (1.92 inches), June (1.26 inches), July (2.27 inches) and August (2.22 inches). First frost generally occurs in early to mid-August. Last frost typically occurs by early to mid-July. Extreme temperatures from 1949 to 2002 ranged from approximately minus 32 to 86 degrees Fahrenheit (Western Regional Climate Center 2003).

In Wyoming's Wind River Range, the bulk of the summer precipitation occurs during June (2-3 inches) and July (2-2.5 inches) at the Spruce Island alpine site (elevation 9,600 feet) and Blueberry Glade subalpine site (elevation 9,600 feet). September precipitation may equal or exceed August precipitation and ranges from 0.5 to 1.5 inches (Scott 1995).

Saussurea weberi exhibits an apparent preference for stabilized tundra slopes on limestone substrates in alpine or subalpine habitats. However, it also has been reported from scree and talus.

Reproductive biology and autecology

The physical and abiotic factors affecting alpine environments have led to a variety of adaptations by alpine species, including over-wintering with both leaf and flower buds in an advanced stage, the ability to concentrate carbohydrate reserves to enable early season growth, the ability to grow under snow (subnivean development), and underground structures such as rhizomes or fibrous roots that allow for over-winter energy storage, enabling rapid growth as the snow melts (Scott 1995). Herbaceous alpine plants may also be adapted to rosette or cushion growth forms that allow survival in some of the least exploited alpine habitats such as exposed ridgetops lacking snow cover and late snow beds with very short growing seasons (Scott 1995). It is unknown how many of these or other adaptations are associated with *Saussurea weberi*.

Several CNHP EORs note that vegetative reproduction occurs via rhizomes, however some other knowledgeable individuals suggest this may be incorrect based on the literature and herbarium specimens (Johnston 2003 personal communication, Scott personal communication 2003). The root is thick, woody, and may sometimes grow horizontally, although it would not be considered rhizomatous, and the species probably does not reproduce vegetatively (Johnston personal communication 2003, Scott personal communication 2003). However, Abbott (1998) reports the species is highly rhizomatous and that vegetative reproduction via rhizomes may be important in maintaining long-term population stability and may limit the genetic diversity of individual populations. In his peer review comments of this document, Abbott offered accounts of several noted herbarium curators that specimens of *Saussurea weberi* do in fact appear to be rhizomatous. In addition, Abbott (personal communication 2004) provided photocopies of two herbarium specimens (RM 467860, Abbott #433, Rocky Mountain Herbarium, Laramie WY; and GREE, Abbott #434, University of Northern Colorado Herbarium, Greeley, CO) that appear to be rhizomatous in the opinion of the author of this assessment.

Abbott noted that rhizomes of *Saussurea weberi* “are extremely brittle and difficult to collect, making it understandable that they are not normally obtained” (Abbott personal communication 2004). Abbott (personal communication 2004) also noted the following in support of the rhizomatous nature of *S. weberi*, “When viewed in the field, shoots of *S. weberi* most often present themselves in clusters; it seems unreasonable to conclude that those shoots, especially where growing

in close proximity, are unconnected belowground, and that those connective structures (based upon the specimens mentioned) are not rhizomes. Furthermore, it seems reasonable to conclude, especially if plants are growing upon less stable substrates, that underground connections do break, and that shoot/root units continue to survive as physically separate individuals, probably eventually producing caudices of their own.” In summary, it is probable that *S. weberi* is rhizomatous, although it is not known for certain. As Abbott stated (personal communication 2004), “a future study either involving extensive, destructive excavation of several shoot clusters, or better, one based upon genetic analysis of shoots within clusters may resolve the question of the rhizomatous nature of *S. weberi*.” Whether or not *S. weberi* reproduces vegetatively has important implications for its on-going survival and management.

There is no other information available pertaining to *Saussurea weberi*’s basic ecology, such as years to reproductive maturity, life stages, population structure, mortality, or seed biology (Wyoming Natural Diversity Database 2003a). The presence of a well-developed, woody rootstock suggests the species is fairly long-lived (Johnston personal communication 2003) and is supported by Abbott’s ongoing study that has tracked what, in many cases, are the same plants, for nine years in fixed sample quadrats. There have been no genetic studies performed on the species (Hartman personal communication 2003, Johnston personal communication 2003).

As an alpine species, *Saussurea weberi* must complete its reproductive cycle during a the brief growing season characteristic of high elevations (Scott 1995). In Wyoming, flowering and fruiting typically occur during July through August (Fertig 2000b, Wyoming Natural Diversity Database 2003a). The presence of a well-developed pappus suggests seed material is readily dispersed via wind (Wyoming Natural Diversity Database 2003a).

Saussurea weberi is reportedly insect pollinated and an obligate out-crosser (Abbott 1998). Flowers in the Asteraceae are relatively small and individually play a relatively minor role in attracting pollinators. The functional pollination unit in the family is usually the head, composed of several to many flowers (Walters and Keil 1996). Abbott (1998) described the generalized development of a single disk flower of *S. weberi* as follows: “As the floret starts to expand, the purple corolla becomes exerted above the mass of pappuses of the head. At first, the corolla lobes overlay the apex of the androecium, but the lobes soon reflex,

exposing the deep-purple collar of united anthers that exserts beyond the corolla throat. Lines of dehiscence and a mass of visible pollen appear at the anther tips, the pollen likely pushed from below by the style of the gynoecium as it elongates up through the middle of the collar. The purple stigma, lobes appressed and covered with pollen, becomes visible as the style continues to elongate. This pollen coverage of the stigma and style may actually enhance presentation to pollinating insects. At some point the stigma lobes reflex, the style elongates further still (exposing white stylar tissue), and the color of the corolla and gynoecium transforms from purple to magenta. Finally, the corolla dries to a dusty rose and pollen is no longer evident upon the androecium, although stigma and style remain fresh for some time after. Anthesis ends with the drying of the stigma and style.” This type of floral development is typical of many Asteraceae (Walters and Keil 1996).

Several pollinators were observed by Fertig in a 1996 survey, including a brown butterfly, a white and black-checked butterfly, and a bee (Wyoming Natural Diversity Database 2003b). According to Abbott (1998), two species of bumblebees, *Bombus frigidus* and *B. sylvicola* are the predominant pollinators for the southernmost population, located in Horseshoe Cirque in central Colorado. A subsequent quantitative study by Spackman, et al. (2001) found a much higher rate of visitation to *Saussurea weberi* by flies (i.e., 6 : 1 ratio of fly : bumblebee visitation) than was realized by the more qualitative approach of Abbott (1998). Abbott (1998) noted that bumblebees typically repositioned stamens across different flowers and dislodged pollen as they walked across the flower heads. Abbott (1998) used morphological characterizations to distinguish the pollen of *S. weberi* collected from bumblebees. Abbott (1998) noted several adaptive characteristics in *S. weberi* that are typical for species pollinated by bumblebees, including a long flowering period of eight days or longer that may serve to offset infrequent visits by pollinators, a subtle sweet-skunky odor that may serve as an attractant at close range, and floral structures that are highly reflective of ultraviolet (UV) light such as the corollas, anthers, and pollen of disk flowers that stand out against the highly UV absorptive mass of pappuses and the background. In Colorado, it has been reported that the larvae of two species of flies may prey upon up to 70 percent of the fruit and seed while still in the flower head of the plant (Abbott 1998; note this observation originated as a personal communication in 1994 from Dr. William Harmon (deceased), former professor of botany at University of Northern Colorado).

This level of predation may pose a significant threat to reproductive success of the affected populations.

The low growth form associated with *Saussurea weberi* may represent an important adaptation to alpine environments (Scott 1995). The net effects of a low growth form are to decrease minimize evaporative loss due to high winds in alpine environments and maximize the benefits of near-ground thermal absorption of solar radiation.

In the Competitive/Stress-Tolerant/Ruderal (CSR) model (Grime 2001), *Saussurea weberi* exhibits a suite of characteristics that most closely approximate those of stress-tolerant species. Examples of stress-tolerant attributes of *S. weberi* under Grime’s model include the presumed long lifespan, adaptations to windy and xeric conditions, caespitose growth form, and a thick woody rootstock. As members of a presumably long-lived species, established *S. weberi* plants are not likely to be adapted for survival in situations of frequent or intense disturbance. However, *S. weberi* is apparently adapted for at least some natural disturbance (i.e., natural sloughing and creep associated with steep tundra and talus slopes), and is occasionally reported from barren, sparsely vegetated, or disturbed habitats. Accordingly, *S. weberi* may be expected to withstand light to moderate disturbance (i.e., in terms of frequency and intensity), but there is no hard evidence to support this premise. The frequent association with stable, late successional communities and apparent long-lived life strategy suggests that *S. weberi* is a fairly strong competitor and predominately a K-selected species (MacArthur and Wilson 2001). However, *S. weberi*’s apparent ability to occasionally colonize unoccupied or sparsely occupied habitats such as barren mine rubble suggests it also exhibits characteristics of an *r*-selected species (MacArthur and Wilson 2001). Seeds from plants growing on exposed sites are probably readily dispersed by wind, at least over short distances, as indicated by the presence of a well-developed pappus. It is less clear how effective wind transport may be across major habitat discontinuities, but it is unlikely that significant transfer occurs between the three major disjunct population centers of *S. weberi*. There is no information pertaining to seed production or viability (Dawson personal communication 2003).

The range of morphologic variability and phenotypic plasticity of *Saussurea weberi* in response to varying environmental conditions such as light and moisture have not been clearly defined. Mycorrhizal relationships are not documented for *S. weberi*.

Figure 8 depicts a life cycle diagram for *Saussurea weberi*. As illustrated by the dashed lines depicting areas of uncertainty, many important components of the relevant life history for this taxon are unknown.

Demography

Saussurea weberi is not known to hybridize. The genetic characteristics of *S. weberi* have not been examined and it is unknown if the occurrences exhibit a high degree of genetic diversity or if it is relatively homogeneous. Information pertaining to life history characteristics (e.g., recruitment, survival, age to reproductive maturity, proportion of population reproducing, etc.) is also lacking. However, *S. weberi*'s disjunct population structure and obligate outcrossing mode of reproduction suggests genetic diversity may be relatively high across its range, especially between the main population centers in Wyoming and Colorado.

The bristly pappus-bearing achenes are adapted for wind dispersal, and wind transport across at least

small areas of unsuitable habitat is likely (Wyoming Natural Diversity Database 2003a). Additional information specific to this species, including life history stages, population structure, mortality, and seed biology, is not available (Wyoming Natural Diversity Database 2003a).

Saussurea weberi does not appear to be a highly disturbance-tolerant species, and would not be expected to respond favorably to repeated disturbance (Johnston personal communication 2003), although it reportedly grows on barren mine rubble in at least one occurrence (Abbott 1998). A study of seed germination and seedling survival (Abbott personal communication 2004) is discussed under Restoration Methods. Seedlings are likely to be the most vulnerable life stage, with a high likelihood of succumbing to drought stress. As with many species, successful recruitment events may be episodic, depending on favorable climatic conditions during flowering and favorable precipitation and soil moisture conditions during the initial establishment period of the first growing season. Patch dynamics at

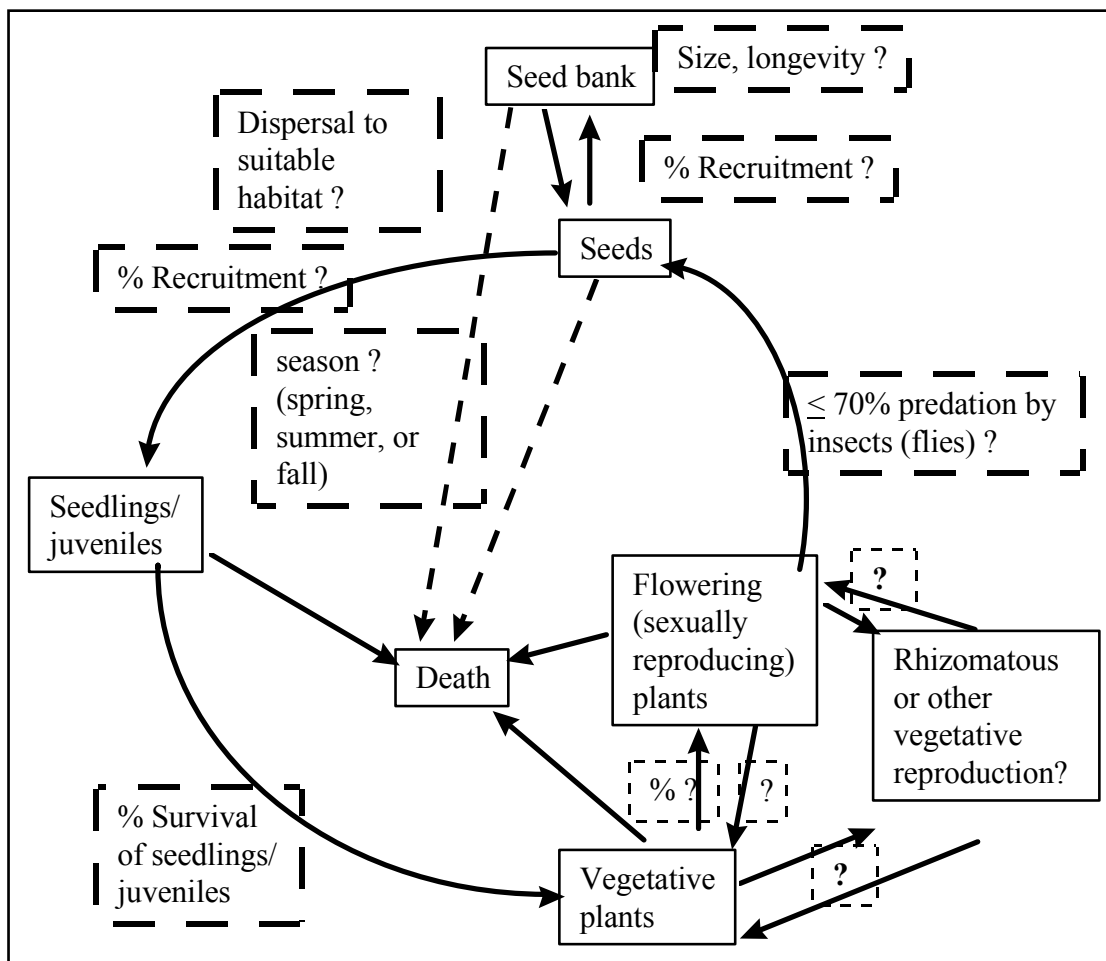


Figure 8. Life cycle diagram for *Saussurea weberi*.

the microhabitat scale likely also influence recruitment success and seedling survival.

It is unclear to what degree geographically separate groups of individuals are demographically linked or how this relates to the resulting population structure and genetic diversity of the species as a whole. However, the relatively vast distances that separate the three main disjunct areas of occurrence in Montana, Wyoming, and Colorado likely serve as effective barriers to transfer of genetic material between the existing population centers. Within each of the population centers, it is possible that genetic transfer occurs between nearby colonies via seed and pollen transport. Bumblebees typically forage over distances of three miles or less and although the species is an obligate out-crosser, cross-pollination may be more important for maintaining intra-population genetic diversity (Abbott 1998). Genetic diversity between nearby populations is probably enhanced through migration of seeds via wind dispersal.

There has been no molecular analysis of genetic variation within and between populations of *Saussurea weberi* (Hartman personal communication 2003). No population viability analysis (PVA) has been reported for *S. weberi* or other North American *Saussurea*.

The largest reported occurrence of *Saussurea weberi* is located on the Bridger-Teton National Forest in Wyoming (WYNDD EOR 003, west of Green River Lakes) and has been estimated at 10,000 to 15,000 individuals. In Colorado, the largest reported occurrence is located on private land in Dolly Varden Gulch and was estimated at 4,500 individuals during one survey (CNHP EOR 012). These areas likely serve as important sources of genetic diversity for the species and may play an important role in occurrence stability, especially with regard to individual population centers. Some narrow endemics have a relatively low degree of genetic variation, suggesting a species has not had a wider range historically. Other species may exhibit a high level of genetic variation, which suggests a wider historical geographic range. A high degree of genetic variation tends to offer population stability benefits, but in the event of a population crash, a species may still be hard hit because of inbreeding depression if numerous recessive alleles are present. Given the discontinuous distribution of *S. weberi*, it is possible the species was more widespread historically (i.e., during the Pleistocene when cooler, wetter conditions at lower elevations may have provided more suitable habitat), but its distribution has likely narrowed in response

to climatic changes that now limit the availability of suitable habitat across its range. As noted previously, this sort of historic distribution, coupled with an out-crossing reproductive strategy, suggests a fairly high degree of genetic variation across its range.

In general, the probability of seed and other propagule dispersal decreases rapidly as distance from the source increases (Glenn-Lewin and van der Maarl 1992). As a result, long distance dispersal events are rare. On the other hand, the likelihood of *Saussurea weberi* dispersal is enhanced by the inherent morphological adaptations of the fruit (i.e., a well-developed pappus) that facilitate wind transport, coupled with windy conditions typical of high alpine environments. Habitat fragmentation may impact pollinator populations and limit effective ranges of pollen transfer since pollinator-mediated pollen dispersal is generally limited by flight distances of pollinators.

It is not known how important or effective gene flow is for maintaining healthy levels of heterozygosity. Cross-pollination within individual colonies and between nearby populations would likely help to maintain some degree of genetic diversity. The pollination ecology of *Saussurea weberi* hasn't been documented across the species' range, although at least one occurrence has been documented to be pollinated by flies and bumblebees (Abbott 1998, Spackman, et al. 2001). As Abbott notes (personal communication 2004), assuming *S. weberi* is rhizomatous, the next-closest inflorescence to any particular inflorescence is likely to be a ramet, and therefore genetically identical. Because *S. weberi* is an obligate out-crosser, the longer trapline-foraging technique of bumblebees probably still makes bumblebees more effective pollinators of *S. weberi* than flies would be. Regardless of the identity of the pollinating insect, a high rate of pollen carry-over may be important for effective pollination within occurrences of this species (Abbott 1998).

As a habitat specialist exhibiting a preference for alpine settings, often in coarse, poorly developed soils derived from calcareous substrates, population sizes of *Saussurea weberi* are naturally limited by availability of habitat. The distribution and physiognomy of habitat for *S. weberi* imposes constraints on population growth at a variety of scales. Although *S. weberi* may be capable of occupying a broader range of habitat, it may not be able to successfully compete in areas with more favorable conditions and more-developed plant communities or competitive species.

Community ecology

Associated species that have been documented in Element Occurrence Records for Colorado and Wyoming are listed in **Table 6** and **Table 7**, respectively (Wyoming Natural Diversity Database 2003b), while associated species reported for the Montana occurrence are reported below. *Saussurea weberi* is associated with vegetated alpine cushion plant communities and to a lesser extent, alpine meadows. In one instance, it was found in the understory of an Engelmann spruce forest just below timberline (Colorado Natural Heritage Program 2003b, Montana Natural Heritage Program 2003b, Wyoming Natural Diversity Database 2003b). In Colorado, the dominant species/community types reported from EORs include *Kobresia myosuroides*, *Geum (Acomastylis) rossii*, *Deschampsia cespitosa*, and *Dryas* in stabilized patches of tundra (Colorado Natural Heritage Program 2003b). In Wyoming, associated species reported from EORs include *Polemonium viscosum*, *Erigeron lanatus*, *Hymenoxys grandiflora*, *Betula glandulosa*, *Salix glauca*, and *Parrya nudicaulis*, but *Saussurea weberi* is reported to be absent from adjacent communities dominated by *G. rossii* (Wyoming Natural Diversity Database 2003b). In Montana, *S. weberi* reportedly occurs with meadow vegetation including *Poa interior*, *Senecio lugens*, *Poa alpina*, *Carex scirpoidea* var. *pseudoscirpoidea*, *Agropyron caninum* var. *latiglume*, and *Arnica rydbergii* (Watson and Lackschewitz 1980, Achuff and Roe 1992, Montana Natural Heritage Program 2003b).

Limiting factors for *Saussurea weberi* are suitable alpine habitat, or to a lesser extent sub-alpine habitat, which consists primarily, although not exclusively, of open talus or scree slopes with calcareous soils associated with limestone or dolomite (Watson and Lackschewitz 1980, Colorado Natural Heritage Program 2003b, Wyoming Natural Diversity Database 2003b). *Saussurea weberi* is not known to engage in competitive, mutualistic, or symbiotic relationships with either native or introduced species.

Saussurea weberi reportedly occurs with several other rare plant species in Colorado including *Braya humilis*, *Ipomopsis globularis*, *Papaver kluanense*, and *Ptilagrostis porteri* (Colorado Natural Heritage Program 2003b). *Saussurea weberi* reportedly occurs with several other rare plant species in Wyoming, including *Androsace chamaejasme* var. *carinata*, *Braya humilis*, *Erigeron lanatus*, *E. radicans*, *Parrya nudicaulis*, and *Physaria (Lesquerella) fremontii*, although the association with *P. (Lesquerella) fremontii* may be questionable (Scott personal communication

2003) (Wyoming Natural Diversity Database 2003b). Parasitic flies have been reported to interact with *S. weberi*, but there are no reported disease relationships associated with *S. weberi* (Abbott 2002).

The role of herbivory in the ecology of *Saussurea weberi* is unknown, although evidence of herbivory has been noted as absent on EORs (Colorado Natural Heritage Program 2003b, Wyoming Natural Diversity Database 2003b, Johnston personal communication 2003). Utilization by small mammals is possible, while high levels of predation of seeds and fruit in flower heads by fly larvae have been noted from some Colorado occurrences (Abbott 1998). Abbott (personal communication 2004) offered the following regarding regular, yet infrequent evidence of predation of *S. weberi* in Colorado: “At least a few inflorescences have been observed each summer for the past decade within the population in Horseshoe Cirque, Colorado, which appear to have been partly or totally eaten. The shape of remaining portions of partially consumed inflorescences suggests that they had been foraged by a large mammal such as an elk, rather than nibbled by a small mammal such as a rodent. The fact that so few inflorescences are found that have been affected in this manner suggests that large mammals find *S. weberi* to be of low palatability, but these observations admittedly provide thin evidence for such a conclusion. However, grasshoppers have been directly observed feeding upon leaves of *S. weberi*, stripping leaves down to the midrib. The overall impression over the past ten years, though, is that the rate of such predation is low and tolerable within the same population described above.”

There is no information on competitors for biotic and abiotic resources with *Saussurea weberi*. If competitive interactions are important in the autecology of *S. weberi*, some of the associated species cited in **Table 4**, **Table 5**, **Table 6**, and **Table 7** are the most probable competitors. However, stress-tolerant species such as *S. weberi* do not typically need to be good competitors, since they are adapted to stress regimes that tend to limit aggressively competitive species.

An envirogram is a graphic representation of the resources and environmental factors that influence the condition of a species and reflects its chance of reproduction and survival. Envirograms have generally been used for animal species, but may also be applied to describe the condition of plant species (Andrewartha and Birch 1984). Environmental factors thought to directly impact *Saussurea weberi* comprise the centrum and the indirectly acting variables form the web (**Figure 9** and **Figure 10**). As noted earlier, adequate

Table 6. Species associated with *Saussurea weberi* from Colorado Element Occurrence Records (EORs) (Colorado Natural Heritage Program 2003b). R = rare plant tracked by the CNHP; * = frequent associate with *Saussurea weberi* (i.e., listed two or more times).

<i>Acomastylis rossii</i>	*	<i>Kobresia myosuroides</i>	*
<i>Armeria scabra</i> subsp. <i>siberica</i>		<i>Kobresia</i> spp.	*
<i>Artemisia</i> spp.		<i>Minuartia</i> spp.	
<i>Astragalus</i> spp. (e.g., <i>A. molybdenus</i>)	*	<i>Papaver kluanense</i>	R
<i>Bistorta bistortioides</i>		<i>Pedicularis</i> spp.	
<i>Bistorta vivipara</i>	*	<i>Pentaphylloides floribunda</i>	
<i>Braya humilis</i>	R	<i>Ptilagrostis porteri</i>	R
<i>Carex</i> spp.	*	<i>Poa alpina</i>	
<i>Castilleja occidentalis</i>		<i>Potentilla diversifolia</i>	
<i>Cerastium</i> spp.		<i>Rhodiola integrifolia</i>	
<i>Claytonia</i> spp.		<i>Salix brachycarpa</i>	*
<i>Dechampsia caespitosa</i>	*	<i>Salix nivalis</i>	
<i>Draba</i> spp.		<i>Salix planifolia</i>	
<i>Dryas octopetala</i>	*	<i>Salix reticulata</i> (listed on EOR, but reportedly does not occur in Colorado)	
<i>Frasera speciosa</i>		<i>Salix</i> spp.	*
<i>Gentian algida</i>		<i>Silene</i> spp.	
<i>Geum rossii</i>		<i>Swertia perennis</i>	*
<i>Hymenoxys grandiflora</i>		<i>Thalictrum alpinum</i>	
<i>Heterotheca pumila</i>		<i>Trifolium dasyphyllum</i>	
<i>Ipomopsis globularis</i>	R; * (listed on 2 EORs)	<i>Trisetum</i> spp.	

Table 7. Species associated with *Saussurea weberi* from Wyoming Element Occurrence Records (EORs) (Wyoming Natural Diversity Database 2003b). R = rare plant tracked by the WYNDD; * = frequent associate with *Saussurea weberi* (i.e., listed two or more times).

<i>Androsace chamaejasme</i> var. <i>carinata</i>	R	<i>Lloydia serotina</i>	
<i>Aquilegia jonesii</i>		<i>Lupinus argenteus</i>	
<i>Arnica angustifolia</i>		<i>Oxyra digyna</i>	*
<i>Astragalus aboriginorum</i>		<i>Parrya nudicaulis</i>	R; * (listed on four EORs)
<i>Astragalus alpinus</i>		<i>Penstemon montanus</i>	*
<i>Astragalus kentrophyta</i>	*	<i>Phlox pulvinata</i>	
<i>Betula glandulosa</i>		<i>Polemonium viscosum</i>	*
<i>Braya humilis</i>	R	<i>Potentilla diversifolia</i>	
<i>Campanula uniflora</i>		<i>Rumex paucifolius</i>	
<i>Chaenactis alpina</i>		<i>Salix rotundifolia</i>	
<i>Cirsium eatonii</i>		<i>Salix arctica</i>	
<i>Dryas</i> spp.		<i>Saxifraga</i> spp.	
<i>Elymus trachycaulus</i>		<i>Saxifraga oppositifolia</i>	
<i>Erigeron compositus</i>		<i>Silene acaulis</i>	*
<i>Erigeron lanatus</i>	R; * (listed on two EORs)	<i>Sedum</i> spp.	
<i>Erigeron leiomurus</i>		<i>Senecio canus</i>	
<i>Erigeron radicans</i>	R; * (listed on two EORs)	<i>Senecio fremontii</i>	*

Table 7 (concluded).

<i>Eriogonum ovalifolium</i>		<i>Senecio amplexans</i> var. *
		<i>holmii</i>
<i>Eritrichium nanum</i>		<i>Smelowskia calycina</i>
<i>Festuca brachyphylla</i>		<i>Telesonix</i>
		<i>heucheriformis</i>
<i>Hymenoxys grandiflora</i>	*	<i>Townsendia incana</i>
<i>Lesquerella fremontii</i>	R	

information is not available to make a comprehensive envirogram for *S. weberi*. The envirograms in **Figure 9** and **Figure 10** are intended to outline some of the known or suspected major variables that directly impact the species and also include some speculative factors that may be tested in the future (i.e., dashed boxes). The lack of direct studies on *S. weberi* increases the need for reliance on observations and inference as a basis for forming opinions.

CONSERVATION

Threats

Across its range, the greatest threats to *Saussurea weberi* are probably environmental stochasticity and

natural catastrophes, with the most foreseeable range-wide threats due to prolonged weather-related variability and potential climate change. Human-related threats to *S. weberi* are somewhat variable, but generally low at present across its range. The primary human-related threats to individual occurrences identified on public lands, including USFS Region 2 occurrences, are off-road vehicle (ORV) activity, and surface disturbance activities associated with road construction and mining (Colorado Natural Heritage Program 2003b). Threats posed by exotic species and non-motorized recreational activities such as hiking are currently thought to be minor. Threats posed by livestock are less certain, as *S. weberi*'s palatability and susceptibility to herbivory are not definitively known, but also generally appear to be low since most known occurrences (including USFS

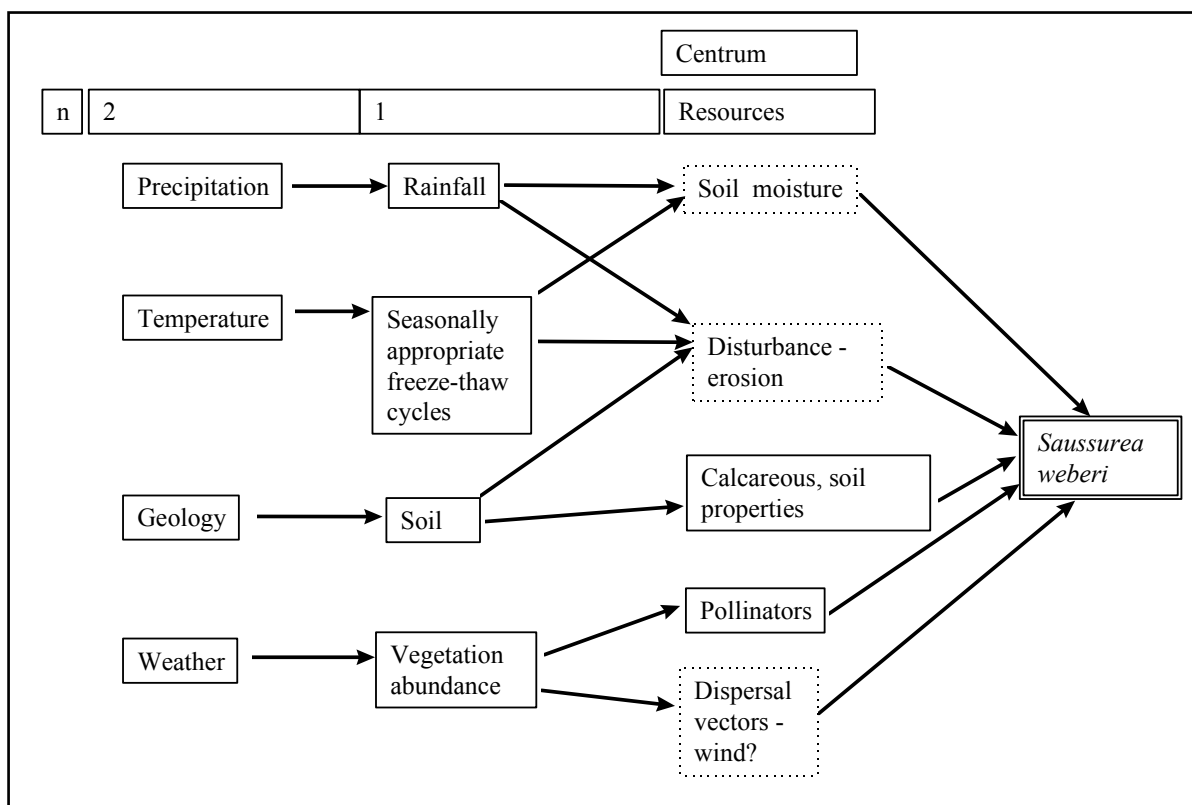


Figure 9. Envirogram outlining the resources of *Saussurea weberi*.

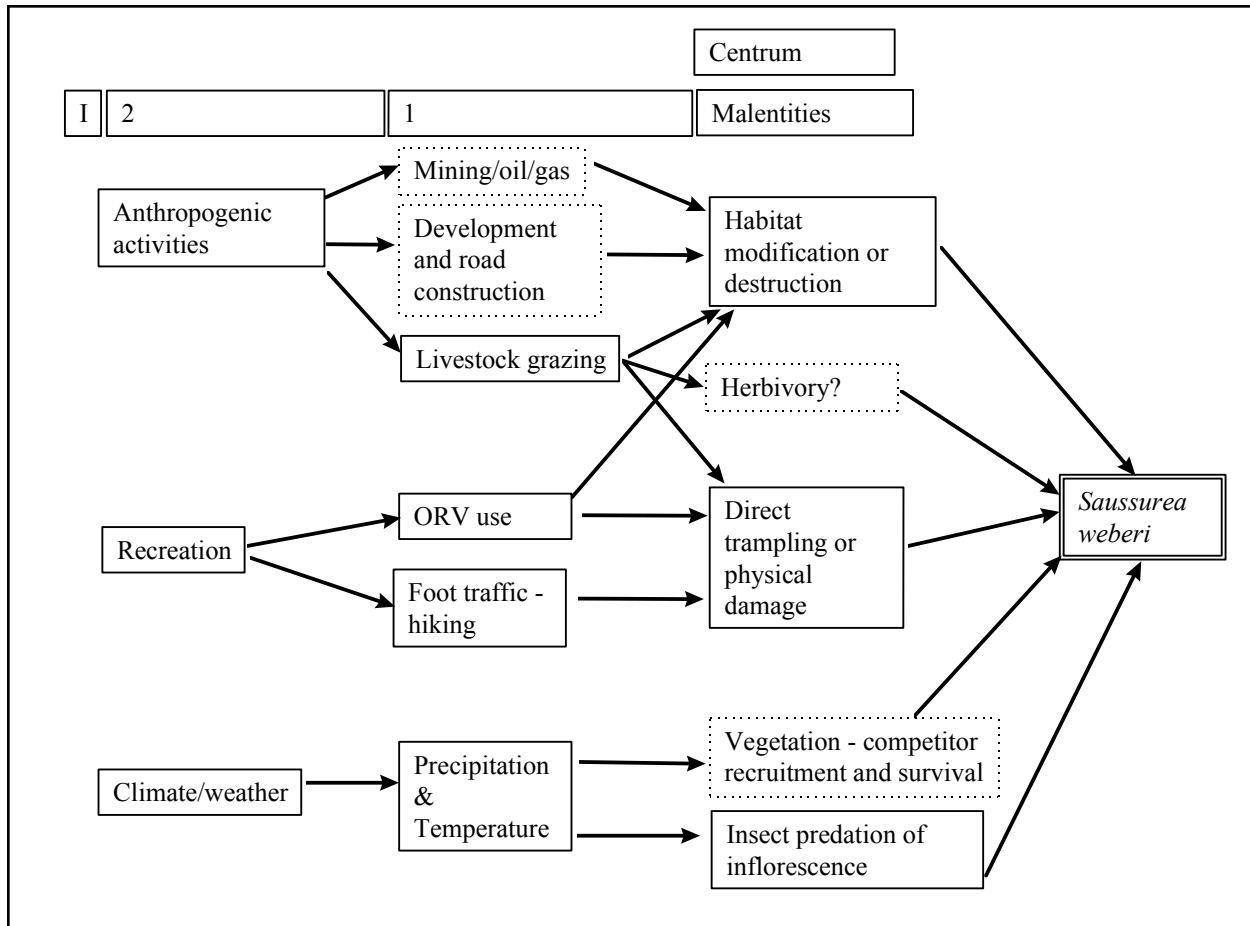


Figure 10. Envirogram outlining the malentities to *Saussurea weberi*.

Region 2 EORs) are either in areas where grazing is not permitted or is unlikely due to sparse vegetation cover and rugged terrain. Development, including road construction and residential development, may pose threats to occurrences of *S. weberi* on private land.

Saussurea weberi does not appear to be a disturbance-adapted species, as shown by its apparent association with successional stable alpine vegetation communities (personal communication Johnston 2003). Since *S. weberi* is a long-lived, stress tolerant, slow-growing perennial, it is likely that occurrences and habitat quality would be negatively impacted by high disturbance activities such as road construction, resource development, and residential development, although individuals reportedly occur on barren mine rubble in at least one Colorado EO (Abbott 1998). It is also likely that it would respond poorly to heavy physical disturbance from heavy livestock or recreational use. Potential indirect effects on habitat quality for *S. weberi* caused by fragmentation may also occur, but are less clear. The impact of these actions on habitat quality

for *S. weberi* depends largely on the importance of ecological connectivity between occurrences, which is not known.

Potential threats to the 17 known occurrences in Colorado include mining, ORV use, grazing, competition from exotic plant species, and non-motorized recreational activities. No formal analysis of threats to the species in Colorado has been completed by the CNHP, but review of available literature and existing EORs indicates the primary threats are disturbance associated with hard-rock mining in its mineral-rich area of endemism, four-wheel drive and other off-road vehicle (ORV) use, and hiking (O’Kane 1988, Colorado Natural Heritage Program 2003b). In Colorado, most EORs suggest that threats to individual occurrences are low at present, but frequently note renewed mining activities and increased ORV use as potential concerns and threats (Colorado Natural Heritage Program 2003b). In Colorado, the presence of non-native mountain goats in alpine habitats where occurrences of *Saussurea weberi* are located may also

pose a threat (Edelmon personal communication 2003), although this has not been evaluated and there are no monitoring data available to accurately assess this issue. On private land in Colorado, including a private in-holding within FS land, development is also a potential concern, in addition to mining and ORV use.

In Wyoming, potential human-related threats to *Saussurea weberi* are generally low to nonexistent (Wyoming Natural Diversity Database 2003a). USFS Region 4 has designated *S. weberi* as a sensitive Species, affording it a high level of protection on National Forest System lands. The largest known occurrence, of up to 15,000 individuals is in an area where grazing is not permitted, and other USFS Region 4 occurrences are located in remote, generally pristine areas of the Bridger and Gros Ventre wilderness areas of the Bridger-Teton National Forest (Wyoming Natural Diversity Database 2003b). Threats for the three Wyoming occurrences in USFS Region 4's Bridger Wilderness are low, while threats to the occurrence in the Gros Ventre Wilderness are listed as unknown (Wyoming Natural Diversity Database 2003b). Threats for the two Wyoming occurrences in USFS Region 2's Fitzpatrick Wilderness on the Shoshone National Forest are low (see **Table 8**). In Wyoming, the presence of bighorn sheep in alpine habitats where occurrences of *S. weberi* occur may pose a threat, although this has not been evaluated and there are no monitoring data available to assess this issue. In Montana, (USFS Region 1), the only occurrence is in the Anaconda-Pintler Wilderness and the only reported threat is from a nearby hiking trail (Achuff and Roe 1992).

Rangewide, there has been no documentation of adverse impacts to, or extirpation of known occurrences by natural events or human activities, including ORV use, road construction, and resource development, although there have been no specific studies to formally assess impacts. However, it is likely that some habitat could potentially be threatened by ORV activity, road construction, or mining in the future. Human-related threats to *Saussurea weberi* are generally low on public lands across its range at present. According to WYNND (2003a), the habitat trend in USFS Region 2 is unknown. However, the remote, rugged nature of the wilderness area occurrences suggests that habitat is not likely to be adversely impacted by human pressures (Houston personal communication 2003). The CNHP has not offered an assessment of habitat trends, but Colorado habitat is likely to be at higher risk overall compared to habitat in Wyoming based on historic land use activities such as mining, a greater potential for ORV use since occurrences are in non-wilderness areas, and potential

for development on private lands (Colorado Natural Heritage Program 2003c).

Resource extraction is a potential threat for occurrences that might be affected by physical removal or burial of populations in conjunction with mining activities. Mining appears to pose the greatest threat in Colorado, and is listed as a potential threat for six of the CNHP EORs, five of which occur on National Forest System lands (CNHP EORs 001, 002, 004, 011, and 019) (Colorado Natural Heritage Program 2003b), although mining activities in the area have generally been curtailed drastically from historic levels. Road construction in the vicinity of occupied or potential *Saussurea weberi* habitat to support mineral extraction may pose a related threat.

Roads might threaten occurrences of *Saussurea weberi* through direct physical disturbance and indirectly as sources of erosion. In obligate out-crossing species such as *S. weberi*, habitat fragmentation due to roads and trails might also raise barriers to pollinators and disrupt effective gene flow. New road construction or right-of-way management and road widening projects may have detrimental effects on the habitat or threaten occurrences of *S. weberi* if they occur in the immediate vicinity or are built in occupied or potential habitat. Occurrences in the vicinity of roads may also be vulnerable to other indirect impacts, such as dust coating of stigmatic surfaces.

Physical destruction associated with off-road vehicle (ORV) recreation is one of the most likely potential threats for the known occurrences of *Saussurea weberi* and is listed as a potential threat for many Colorado occurrences, including five of which occur on USFS land (CNHP EORs 001, 002, 004, 011, and 019, Colorado Natural Heritage Program 2003b). ORV use may also disrupt the activities of pollinators or foul the stigmatic surfaces of flowering plants in the vicinity through deposition of dust. Habitat fragmentation may adversely impact pollinator access to various populations and restrict gene flow.

It is unknown if *Saussurea weberi* is palatable to, or browsed by domestic livestock or native or introduced ungulates, so the threat from herbivory is not known. It is not known if mountain goats or bighorn sheep, which routinely access alpine terrain, pose a threat to *S. weberi*. Herbivory has not been reported as a problem in EORs or heritage program reports. However, trampling by livestock may pose a threat. Assuming the species is somewhat tolerant of light to moderate disturbance; it is likely to adequately withstand impacts of dispersed,

Table 8. Summary of threats to *Saussurea weberi* on various federally managed lands. Bold type = USFS Region 2 occurrence.

Agency	Region/State	Special management areas with known occurrences	Grazing	ORV/4WD	Mining
USFS Region 1	Beaverhead-Deerlodge National Forest (Montana)	Anaconda-Pintler Wilderness	unknown	none - not allowed in Anaconda-Pintler Wilderness	unknown
USFS Region 2	Shoshone National Forest (Wyoming)	Fitzpatrick Wilderness, including proposed Arrow Mountain Research Natural Area and Whiskey Mountain Bighorn Sheep Habitat Management Unit	low - active allotments, but livestock are not expected to frequent areas of known EORs	none - not allowed in Fitzpatrick Wilderness	none - not allowed in Fitzpatrick Wilderness
	Pike and Arapaho (White River) national forests (Colorado)	Hoosier Ridge Research Natural Area	low - no active allotments	low at present, ORV use is restricted to designated trails and roads, but potential for future increase or abuses exists	low at present, but potential for future increase, not many viable mineral deposits in known areas of <i>Saussurea weberi</i> occurrence (Johnston 2003)
USFS Region 4	Bridger-Teton National Forest (Wyoming)	Gros Ventre Wilderness and Bridger Wilderness, including Osborne Mountain Research Natural Area (<i>Saussurea weberi</i> is cited as part of basis for establishment)	low to unknown, largest known EO is in area where grazing is not permitted; area in Osborne Mountain Research Natural Area has never been grazed by domestic livestock	none - not allowed in Gros Ventre and Bridger wilderness areas	unknown
BLM	Colorado	Mosquito Pass Area of Critical Environmental Concern	no active allotments	low at present, but potential for future increase	low at present, but potential for future increase

infrequent sources of disturbance such as occasional livestock traveling through known occurrences. Heavy trampling is unlikely to be well-tolerated by *S. weberi*, but does not appear to pose a threat at present due to the relative absence of livestock from its occupied habitat, even in areas where livestock grazing occurs.

Exotic species do not pose an appreciable threat at present. None of the Wyoming or Colorado state or county-listed noxious weeds or the invasive species *Bromus tectorum* are noted in any EOR species lists (Colorado Department of Agriculture 2003, Wyoming Weed and Pest Council 2003a, 2003b). The threat of *B. tectorum* invading the subalpine to alpine habitat characteristic of most *Saussurea weberi* occurrences is likely minimal. However, several invasive weeds,

including yellow toadflax (*Linaria vulgaris*), spotted knapweed (*Centaurea biebersteinii*), and scentless chamomile (*Matricaria perforata*) have been reported at or above treeline in Colorado and may pose a threat to endemic alpine species, including *S. weberi*, in the future (Ray 2001).

Non-motorized recreational activities may threaten *Saussurea weberi* occurrences through trampling or erosion. No evidence of damage to any occurrence from non-motorized recreational activities has been reported to date, although there have been no specific studies to formally assess impacts. Assuming the species is somewhat tolerant of light to moderate disturbance, it is likely to adequately withstand impacts of dispersed, infrequent sources of disturbance such

as occasional hiking or scrambling through known occurrences (Wyoming Natural Diversity Database 2003b). Because *S. weberi* is probably a long-lived, stress tolerant, slow-growing perennial, it is likely that it would respond poorly to disturbance from heavy recreational use.

Since the species does not occur in forested areas, timber harvest and blowdown are not significant threats. There are no known commercial or medicinal uses for *Saussurea weberi*, although certain Asian species of genus *Saussurea* reportedly may have medicinal uses (Joshi and Dhar 2003). Due to small population sizes, *S. weberi* would be vulnerable to harvesting if it became sought after for any reason. Over-collection for scientific purposes, particularly in small occurrences, is also a potential threat. In general, present threats posed by over-utilization for commercial, scientific, or educational purposes are minimal.

The minimum viable population size is not known for *Saussurea weberi*, but even small populations may be viable and of conservation importance. Any loss of existing occurrences may result in decreased genetic diversity and disturb metapopulation dynamics.

Global climate change as a result of elevated atmospheric carbon dioxide levels is likely to have wide-ranging effects in the near future. Climate-induced changes to environmental variables such as temperature and seasonality and amount of precipitation may directly impact individual plant species and ecosystem processes such as nutrient cycling, as well as vapor pressure gradients and a suite of other environmental variables. Climate modeling for Wyoming suggests that by the year 2100, average temperatures will increase 4 to 5 degrees F from spring through fall, and 6 degrees F in winter (US Environmental Protection Agency 1998). Precipitation is predicted to increase 10% in spring and fall, and 30% in winter, but decrease slightly (less than 10%) during summer (US Environmental Protection Agency 1998). Similar effects have been predicted for Colorado. This could be a significant threat to alpine species such as *Saussurea weberi* as available alpine habitat is likely to shrink further under global warming scenarios. Increased temperatures in the Rocky Mountain region of Colorado could cause vegetation zones to climb 350 feet in elevation for every degree Fahrenheit of warming (US Environmental Protection Agency 1997). Seasonal shifts in precipitation may also affect plant reproduction and recruitment by reducing seedling survival. Effects specific to *S. weberi* and its habitats are likely to be adverse and significant if alpine environments are lost or further reduced by global

warming. Sustained or dramatic warming may threaten its future survival.

The relatively remote locations that support occurrences of *Saussurea weberi* suggest that effects of atmospheric pollution are likely to be minimal. The tolerance of *S. weberi* to heavy metals and other pollutants has not been investigated.

The effects of fire and fire suppression on habitat quality are likely minimal in the solifluction lobes and alpine talus slopes occupied by *Saussurea weberi*. The role of fire in these habitats is probably minor, and many of the species that occupy these areas are probably not fire adapted. Furthermore, while ecosystem processes in the surrounding alpine environments may directly or indirectly affect *S. weberi* and its habitat quality, fire is not likely to be important in the maintenance of these processes (Johnston personal communication 2003).

In summary, global climate change and weather variation may pose the greatest threat to the species across its range. No adverse impacts to individuals and occurrences of *Saussurea weberi* resulting from management-related activities have been reported to date. However, *S. weberi* populations may be vulnerable to impacts from a variety of threats, primarily ORV use, disturbance from road construction, and residential or mineral development. At present these threats are believed to be low on public land across the species' range. The two occurrences on private lands in Colorado remain at risk of residential development or road construction.

Conservation Status of the Species in Region 2

There have been no studies to assess whether the distribution or abundance of *Saussurea weberi* is changing within USFS Region 2, which encompasses a large portion of the global range of this rare alpine plant. There is no direct evidence that its distribution or abundance is declining or has been impacted by human activities within USFS Region 2. There is no strong evidence that any individual occurrences in USFS Region 2 are at risk. There appears to be considerable variability through time in the population sizes reported for a number of CNHP EORs, although the underlying reasons for the variability are not clear at this time (Colorado Natural Heritage Program 2003b). In addition, some occurrences have not been visited since their discovery to assess or re-assess their status. *Saussurea weberi*'s rarity is apparently the result of a naturally small number of occurrences across a limited

geographic range. Persistence and sustainability of *S. weberi* may rely on relatively long-lived mature individuals. Management practices that allow increased disturbance frequency or intensity, or additional disruptions may adversely affect population viability. To date there have been no population trend studies of the 16 known occurrences on lands administered by USFS Region 2. The high variation in population size and density documented thus far in occurrences suggests that habitats vary substantially in their capacity to support *S. weberi*. However, the underlying ecological reasons for this variation are unknown and difficult to speculate on until research reveals more details of the relationship between *S. weberi* and its habitat. Seven of the USFS Region 2 occurrences of *S. weberi* in Colorado and one in Wyoming have not been visited or assessed since 1990. If these occurrences remain extant, they need to be relocated before they can benefit substantially from any conservation actions. As a result, these occurrences are at risk simply due to the lack of knowledge regarding their status.

Although there has been no analysis of the effects of various management practices on the habitat of *Saussurea weberi*, some inferences can be made based on the nature of these habitats. The location of all Wyoming and Montana EORs within designated wilderness areas and RNAs, and one Colorado EOR in the Hoosier Ridge RNA affords an added level of protection to those occurrences against activities such as ORV use. In Wyoming, the remote, rugged terrain that provides habitat for *S. weberi* is also probably somewhat resilient to impacts that might cause light or moderate disturbance (e.g., infrequent recreational use such as hiking). The remaining occupied areas can probably withstand occasional human visitation without severe effects, although frequent or moderate-to-heavy use by ORVs would probably degrade these sites. Management changes might be necessary if human use of areas supporting occurrences of *S. weberi* increases or changes.

There is no evidence to suggest that occurrences of *Saussurea weberi* are especially vulnerable to habitat change or other changes in the environment, and there is no evidence to suggest the species' habitat is declining or that current management is otherwise placing demands on the species. The species' vulnerability is related to its specific habitat requirements; i.e., alpine habitats with coarse soils derived from limestone, dolomite, or other calcareous substrates. If it is an obligate out-croser as is thought, it is also vulnerable to impacts that affect its pollinators. The lack of exotic species in USFS Region 2 *S. weberi* occurrences suggests competition from

invasion by exotic species is unlikely, although new exotic species may pose problems in the future.

The relatively dispersed nature of disjunct *Saussurea weberi* population centers over a fairly broad geographic range suggests it may be resistant to demographic or environmental stochasticity. However, within a given population center it may be more vulnerable to habitat or environmental change. As a long-lived, stress-tolerant perennial, *S. weberi* may be buffered somewhat from the effects of short-term environmental stochasticity such as drought. The several thousand foot elevation range of *S. weberi* may also buffer it somewhat from climate change impacts that are most likely to affect low elevation populations first, although sustained warming trends may threaten its long term survival.

Potential threats to the 16 known occurrences on lands administered by USFS Region 2 include mining, ORV use, grazing, competition from exotic plant species, native and non-native ungulates such as bighorn sheep and mountain goats, and non-motorized recreational activities. As noted previously, most EORs on USFS Region 2 lands in Colorado are not currently threatened, but renewed mining activities and increased ORV use are potential concerns and threats (Colorado Natural Heritage Program 2003b). A portion of one occurrence (CNHP EOR 003) is afforded higher protection due to its location in the Hoosier Ridge RNA, which was established for protection of a suite of rare plant species, including *Saussurea weberi* (USDA Forest Service 1991, 1994). The only occurrence on BLM land (CNHP EOR 006) occurs in Colorado and is afforded additional protection due to its location in BLM's Mosquito Pass ACEC, which was established for protection of a suite of rare plant species (Bureau of Land Management 1996, Brekke personal communication 2003, Dawson personal communication 2003). Although the Mosquito Pass ACEC is not managed specifically for *S. weberi*, the area receives an increased management focus because of the ACEC designation for protection of rare plants. Colorado BLM's designation of *S. weberi* as a sensitive species provides a heightened level of awareness and protection for the plant, including the need for pre-project surveys in occupied or potential habitat (Bureau of Land Management 2001). The largest occurrence in Colorado (CNHP EOR 012) is on private land with no protection, and may potentially be vulnerable to a variety of activities, including development. Forest Service occurrences in Colorado may not have adequate protection at this time since the species has no special management status and is consequently afforded less consideration in management decision-making.

Increased human visitation to occurrences of *S. weberi* in Colorado will likely continue to pose a threat, as will the increasing popularity of off-road vehicles and potential road construction and mineral extraction.

In Wyoming, on USFS Region 2-administered lands, threats to the Arrow Mountain EO are low overall, while the threats to (and size of) the Whiskey Mountain EO are reportedly unknown, possibly since the occurrence hasn't been relocated since 1984 (Wyoming Natural Diversity Database 2003b). These two populations in the Fitzpatrick Wilderness on the Shoshone NF are subject to a low threat from livestock grazing in the area, as well as possible small-scale effects from hiking or pack animals (Houston personal communication 2003).

Six USFS Region 2 occurrences in Colorado mention mining as a potential threat (Colorado Natural Heritage Program 2003b), although the potential for resource extraction in the vicinity of known occurrences in USFS Region 2 is generally low, as many of the limestone areas occupied by *Saussurea weberi* are not heavily mineralized (Johnston personal communication 2003). The North Star Mountain (CNHP EOR 021) occurrence in Colorado, which spans the Arapaho and Pike national forests, is reportedly threatened because the water source for the site that supports *S. weberi* originates from a pipe that drains from mining tailings, although few details are provided on the EOR (Colorado Natural Heritage Program 2003b). The recent Christine Mine Proposal on the Dillon District of the Arapaho National Forest involves potential access roads in the general vicinity (e.g., within the same section) of a known *S. weberi* occurrence (CNHP EOR 018) on Quandry Peak (Edelmon personal communication 2003). This is an example of the type of project where *S. weberi* would benefit from pre-project surveys or at least an impact analysis that would be required if the species had special management status in USFS Region 2. The potential for resource extraction in the vicinity of known occurrences in USFS Region 2 on the Shoshone NF is low since mineral and oil and gas rights were withdrawn as part of the Fitzgerald Wilderness designation and the potential for resource extraction in adjacent areas (i.e., T40R106W, portions of Sections 13 and 23) on the Shoshone NF beyond the Fitzgerald Wilderness is low (Cawrse personal communication 2003).

Right-of-way management and road widening projects may pose potential threats to some USFS Region 2 Forest Service occurrences in Colorado that

are located in the immediate vicinity of roads (e.g., CNHP EOR 019).

In USFS Region 2 national forests that support *Saussurea weberi*, ORV use is only allowed on existing trails and roads. However, in Colorado, six of the Arapaho/Pike NF occurrences are noted as being at risk by increased ORV use, presumably due to concerns about illegal use beyond approved roads and trails. At least 10 of the Colorado USFS Region 2 EORs are located within approximately one mile of an existing road (Colorado Natural Heritage Program 2003b). The Shoshone NF occurrences are minimally threatened by ORVs as they are not located in the vicinity of any existing roads and ORV use is not permitted in the Fitzpatrick Wilderness.

Livestock grazing does not appear to pose a significant threat in Colorado at present, as none of the Colorado EORs on USFS Region 2 or BLM lands are in active grazing allotments (Atchley personal communication 2003, Brekke personal communication 2003, Olson personal communication 2003). The Whiskey Mountain EO on the Shoshone NF is in an active cattle allotment. The Whiskey Mountain occurrence plants are not located in areas expected to be frequented by livestock since they occur mostly on sparsely vegetated slopes or talus where cattle would not be expected to forage, and are a mile or more from the primary water source, a spring in T40N R206W Section 7 (Russell personal communication 2003, Houston personal communication 2003). This part of the Whiskey Mountain allotment is also used by recreational saddle stock (i.e., horses) owned by the same guest ranch that owns the cattle, by elk and bighorn sheep hunters, and by the Whiskey Mountain bighorn sheep herd, which is in the Whiskey Mountain area most of the year (Russell personal communication 2003). The Arrow Mountain EO on the Shoshone NF is in the Red Creek Allotment, which is closed to commercial livestock grazing, but which is used substantially by the public during hunting season and summer horse-pack trips into the Wind River Range (Russell personal communication 2003). There is some unauthorized use in the lower ranges, by outfitter's horses and occasionally by cattle from the Wind River Indian Reservation, although cattle use does not extend into the alpine areas (Russell personal communication 2003). The potential for trampling in these areas is therefore low. However, there are no recent monitoring data to verify a lack of impacts (Houston personal communication 2003), and changes in range management practices on the Shoshone NF could adversely impact *Saussurea weberi* occurrences

in the future, especially if livestock stocking rates are increased or if water developments are placed in the vicinity of the Whiskey Mountain or Arrow Mountain occurrences. Similarly, on the Arapaho and Pike national forests, adverse impacts could occur in the future if changes in management were to allow grazing in areas containing *S. weberi* occurrences.

Non-motorized recreation such as mountain-biking is not permitted in wilderness areas, but may pose a minor threat to some occurrences on USFS lands in Colorado, none of which are in designated wilderness areas. Non-motorized recreation such as hiking may pose a low threat to some populations in the vicinity of trails, but no direct impacts have been noted to date (Colorado Natural Heritage Program 2003b, Montana Natural Heritage Program 2003b, Wyoming Natural Diversity Database 2003b). The USFS Region 2 occurrences in Wyoming, on Whiskey Mountain and Arrow Mountain, are both within one mile of popular hiking trails on the Shoshone NF. Similarly, on the USFS Region 2 occurrences in Colorado, at least 10 occurrences are in the vicinity of roads and/or trails. It is possible that off-trail hiking could be damaging to USFS Region 2 occurrences in the future.

In summary, the long-term conservation status in USFS Region 2 is not known for certain, but current threats to known occurrences are believed to be generally low. Lack of designation of *Saussurea weberi* as a USFS Region 2 sensitive species may place as-yet-unknown occurrences at risk, since no special pre-project surveys are required for the species. Depending on future management direction and proposals for resource development, occurrences on the Arapaho and Pike NF's may be threatened in the future by ORVs, road construction, or mineral development, although none of these activities actively occur in the vicinity of known occurrences. Livestock grazing on lands administered by USFS Region 2 generally does not pose a significant threat since none of the Arapaho/Pike NF EORs in Colorado are in active grazing allotments and the two Shoshone NF EORs in Wyoming are in rugged, sparsely vegetated terrain that does not lend itself to grazing. The potential for increased recreational ORV use in the remote areas that support *S. weberi* may result in increased threats on USFS Region 2 lands in Colorado in the future. Occurrences on the Shoshone NF are presently subject to minor threats of trampling or localized physical disturbance by livestock and non-motorized recreational activities such as hiking.

Management of the Species in Region 2

Implications and potential conservation elements

No specific management practices have been applied in USFS Region 2 for *Saussurea weberi*. Biological, ecological, and natural history information available for *S. weberi* is generally lacking and limits the analysis required by this section. The most current data available suggest *S. weberi* is imperiled due to small population sizes and the low number of occurrences. Maintaining the genetic integrity of populations of *S. weberi* is an important management consideration, although there are presently no molecular data to assess genetic variation within or between populations and no genetic research is underway (Hartman personal communication 2003). The loss of any occurrence is significant to a rare species, and may result in the loss of important components of the genetic diversity. As disjunct occurrences, the major population centers of Colorado and Wyoming may serve as important sources of genetic diversity for this species. It is possible that populations near the limits of the species range and populations in more extreme habitats have alleles not present in other populations, so loss of these populations might result in a significant loss of genetic diversity.

The USFS Region 2 occurrences are central to *Saussurea weberi*'s overall distribution and are likely important to the overall genetic diversity of the population. As such, USFS Region 2 conservation priorities include conserving and assessing population trends for the 16 known occurrences, assessing the need for listing as a sensitive species, and conducting additional surveys and pre-project surveys for any future proposed surface disturbance activities in areas of occupied and potential habitat (discussed further in Tools and Practices). Since 21 of the 24 known occurrences are on National Forest System lands in USFS Regions 1, 2, and 4, coordinated Service-wide conservation efforts would go a long way toward protecting *S. weberi*. USFS Region 2's support of efforts to characterize the ecology and demographics of this species would also be beneficial by including USFS Region 2 occurrences in any future studies. Since only one of the Colorado USFS Region 2 occurrences is in a protected area (CNHP EOR 003 in the Hoosier Ridge RNA), existing threats will likely continue and may even increase in the future, depending on management and resource needs and trends. Because occurrences of *S. weberi* probably remain to be documented, surveys should take place before management actions within potential habitat.

Desired environmental conditions for *Saussurea weberi* include sufficiently large areas where the natural ecosystem processes on which *S. weberi* depends can occur, allowing it to persist unimpeded by human activities and their effects. This includes a satisfactory degree of ecological connectivity between occurrences to provide corridors and other nectar resources for pollinators if necessary. Given the location of all Wyoming occurrences, including the largest known occurrences in USFS Region 4, in wilderness areas and RNAs, it is reasonable to assume that many of the important conservation measures noted above are being met across portions of the species range. The protection afforded by special management areas is somewhat offset by the nearly total lack of detailed information regarding this species. It is probable that most or all of the ecosystem processes on which *S. weberi* depends are functioning properly at many of the occurrences, particularly in designated wilderness areas. Monitoring of existing occurrences and further research on the genetics, ecology, and distribution of *S. weberi* will help provide information that can be used to develop effective approaches to management and conservation in areas with lesser protection. Until a more thorough understanding of the population trend, distribution, and ecology of this species is developed, priorities lie with conserving the known occurrences, particularly those that support large numbers of plants, are in excellent condition, and in which the surrounding landscape remains largely intact. The locations of the largest known occurrences in special management areas such as the Bridger and Fitzpatrick wilderness areas and Mount Osborne RNA provides an added measure of protection for the species. The location of the largest known occurrence in Colorado on private land may provide an opportunity for protection by the USFS through a land exchange, as it is adjacent to USFS land.

Considering the changes predicted in the global climate for the next 100 years, maintenance of a variety of habitat features and functional ecosystems across a range of higher elevations or latitudes may help to ensure *Saussurea weberi*'s long-term viability. These efforts can be incorporated into preserve designs and conservation plans. Other proactive measures could include closures to ORV use in the vicinity of known occurrences that are most vulnerable, and appropriate restrictions on other development activities such as road construction or mining in the vicinity of known occurrences. Management approaches that focus on "steering" recreational activities such as hiking, climbing, and camping away from known occurrences would also benefit the species. The White River NF has included *S. weberi* on its list of "Species Needing

More Baseline Inventory", and USFS biologists will be looking for additional occurrences on the forest this summer (Edelmon personal communication 2003). Formal designation of *S. weberi* as a USFS Region 2 sensitive species would help to strengthen conservation efforts for the species.

Tools and practices

The priorities for *Saussurea weberi* at this time include initiating a monitoring program to assess population trends and gathering more complete baseline data on distribution and population sizes. Related areas of interest include better characterization of habitat requirements and environmental factors that control the distribution of *S. weberi* and its long-term population dynamics. Finalizing RNA status for the proposed Arrow Mountain RNA on the Shoshone NF would provide further protection for the species in USFS Region 2.

Habitat-level, species-specific surveys have been conducted throughout much of Wyoming. The distribution of *Saussurea weberi* in Wyoming on the Shoshone National Forest has been well documented (Marriott 1988 and 1991), although some minor gaps of survey coverage may exist as noted earlier (Scott personal communication 2003).

Some of the older EORs lack important data such as population size and thorough habitat and associated species descriptions, especially the Colorado occurrences located on private land. Most of the more recent EORs provide more comprehensive data. To date there has not been a species-specific, habitat-level inventory conducted for *Saussurea weberi* that would provide a thorough documentation of occurrences within Colorado. This may be due to inadequate characterization and mapping of suitable habitat, as well as other priorities or lack of resources to perform the work. Once potential habitat is better delineated, perhaps through intersecting GIS layers of precipitation, elevation, slope angle, geology/soils, and vegetation type, comprehensive surveys for *S. weberi* could be focused in areas with suitable habitat. In Colorado, maybe only half of the potential habitat has been surveyed, and areas identified in the Sawatch Mountains on the Gunnison NF would serve as a good starting point for additional Colorado surveys (Johnston personal communication 2003). Additional potential habitat in Colorado may occur in portions of the San Juan Mountains where alpine tundra is underlain by Leadville limestone or Manitou Dolomite.

Periodic follow-up surveys (e.g., every five or 10 years) of occupied and potential habitat would verify the persistence of known occurrences, identify new occurrences and provide insights as to whether occupied range and occurrences are increasing, holding steady, or decreasing. Periodic resurveys of known sites would also be useful in assessing management needs.

Inventories for *Saussurea weberi* are facilitated by the relative ease of field identification, since it is not readily confused with other species in Wyoming and Colorado. Monitoring and surveys of new occurrences would be most accurate if conducted during the flower/fruiting period from mid-July to mid-August. Follow-up visits to known occurrences could be conducted earlier during the flowering period to better characterize pollination strategies and pollinators (Abbott 1998). Contracting experts on this species to search for more occurrences and update historic records (particularly in Colorado) would contribute greatly to our knowledge of *S. weberi*.

Other than Abbott's ongoing work on the Horseshoe Cirque occurrence in Colorado (see discussion under Population Trend), no other population monitoring has been performed to date for *Saussurea weberi* and there are no firm range-wide population trend data as a result. An appropriate expanded monitoring approach would include collection of additional qualitative trend line data (e.g., estimation of population size by tallying the number of individuals, flowering individuals, size of colony, etc.) for other occurrences. This type of trend data, perhaps combined with photo-point monitoring, may be used to assess the stability of existing occurrences through time (Elzinga et al. 1998). A demographic monitoring program that addresses recruitment, seed production plant longevity, and pollinators would generate data useful to managers and the scientific community. Although interpretation of demographic data may be problematic initially, since no baseline data exist for this species in terms of year-to-year fluctuations, habitat specific variability, etc., over time the accumulated data may provide very useful insights. If a substantial decrease is observed between visits (e.g., arbitrarily defined as 25 percent or greater), more sophisticated follow-up monitoring approaches could be devised and implemented as necessary to better assess microsite environmental requirements and population trends. This may also serve as a trigger to review management practices. Population monitoring efforts in USFS Region 2 could be coordinated with monitoring efforts in USFS Regions 1 and 4, and on BLM lands in Colorado, in order to better assess trends for the species across its range.

As a first step, documentation of existing occurrences of *Saussurea weberi* utilizing a GPS system to more precisely document colony locations might be beneficial for coarse level monitoring and follow-up. A simple approach of estimating colony size and density, and mapping boundaries of the known colony(ies) with GPS, could provide important baseline data. Follow-up monitoring may be repeated every two to five years. Due to the time required to visit the many known occurrences, presence/absence monitoring should always be supplemented by population tallies or other estimation techniques that can typically be accomplished without much additional time.

In order to best assess population trends across its range, monitoring should include representative sites from each of the disjunct population centers (e.g., Colorado and Wyoming in USFS Region 2). Possible sampling approaches for more formal monitoring programs involving permanent reference plots might include randomly arranged systematic sampling or a stratified random design (Elzinga et al. 1998). In the first approach, sampling units might consist of transects with evenly spaced quadrats or standard nested frequency frames, with the first quadrat randomly placed along the transect. Transects may need to be relatively short (e.g., less than 10 meters), because many of the Colorado occurrences tend to occupy relatively small areas, and could be readily monumented with a 12 inch nail (Johnston personal communication 2003). Elzinga et al. (1998) offer guidelines for determining optimal quadrat shape and size. Placement of the sampling units would be fixed for future monitoring. Data collection could consist of simple tallies or nested frequency data, possibly with subsets to include flowering individuals, non-flowering individuals, and seedlings. Better insight into plant longevity, recruitment and survival could be accomplished by marking *Saussurea weberi* plants using an aluminum tag or other field marker to track small scale shifts over time, but this approach would be time intensive for data collection and analysis, and would be most meaningful if site visits were scheduled every two or three years. Estimating the cover and/or abundance of associated species within the plots described above could permit the investigation of interspecific relationships through ordination or other statistical techniques. Understanding the environmental constraints on *S. weberi* would facilitate the management of this species. Gathering data on edaphic characteristics (i.e., moisture, texture, and soil chemistry if possible) from the permanent plots described above might be useful for analysis of species-environment relationships and would facilitate hypothesis generation for further studies of the ecology of this species.

A stratified random design might also be employed to establish the sampling units, particularly at locations where it is difficult to establish a linear transect due to the ruggedness of the site. Permanent plots could be selected within a habitat unit by randomly choosing UTM coordinates then physically located using an accurate GPS unit. For future monitoring visits, a recreation grade GPS is usually suitable for relocating plots. If subsequent power analysis of data indicates that sample size is inadequate, it is easy to add more quadrats in this sample design. Disadvantages to this method include the difficulty in using GPS in narrow canyons.

Detailed population monitoring of *Saussurea weberi*, coupled with collection of basic community ecology, autecology, and phenology data will yield greater insights to the species' pollination ecology, variability in plant size, flowering period, seed set rate, reproduction rates, recruitment, lifespan, seedling survival rates, etc. These efforts could be conducted to varying degrees depending on the desired objectives and available resources.

Meaningful population trend data could probably be obtained from monitoring a subset of known occurrences of *Saussurea weberi* on Forest Service lands in USFS Regions 1, 2, and 4. Selecting monitoring sites throughout the range of *S. weberi* at a variety of substrates, elevations, and human usage patterns will provide more meaningful data regarding population trends and responses to stressors. The use of photopoints for population and habitat monitoring is a powerful qualitative technique that can be done quickly in the field and may help to support and clarify patterns observed in quantitative data (Elzinga et al. 1998, Hall 2002). Including photo points in a monitoring program would also facilitate the tracking of individuals (Elzinga et al. 1998). Monitoring sites should be selected carefully, and a sufficient number of sites selected as the variability of the data suggest in order to detect population trends with high confidence. Selection of occurrences where *S. weberi* co-occurs with other rare taxa, such as *Androsace chamaejasme* var. *carinata*, *Braya humilis*, etc., would provide important information on several rare species at once.

Visiting occurrences mid-late summer while the plants are flowering would allow further research regarding insect visitors, as they appear to play a crucial role in the breeding biology of *Saussurea weberi* (Abbott 1998). Abbott (personal communication 2004) suggested that a study using pollination exclosures of varying mesh sizes could clarify the contribution of flies

and bumblebees to pollination of *S. weberi*. One control group of plants could be covered with no exclosures, a second control group with exclosures of a large mesh size to allow entry by both flies (typically smaller) and bumblebees. An experimental group could be established with exclosures of a mesh size small enough to exclude bumblebees, yet large enough to allow flies entry, thereby allowing a comparative assessment of the role of the two pollinator groups.

Measuring seed production and predation is also likely to be important and will require another visit later in the summer, although effective timing will be critical to ensure accurate data are collected before dispersal.

Currently, detailed habitat monitoring in the absence of *Saussurea weberi* individuals cannot be effectively conducted due to the lack of specific, detailed knowledge of habitat requirements. However, expanded survey, inventory, and population monitoring may yield more precise characterization of high quality potential habitat and allow for meaningful monitoring of high quality un-occupied habitat in the future.

For sites that are occupied by *Saussurea weberi*, habitat monitoring should be conducted concurrently with population monitoring. Descriptions of habitat characteristics and condition in conjunction with population monitoring efforts will provide important information. This could be incorporated into the field forms used for the quantitative sampling regimen described above. If carefully selected environmental variables are quantified during monitoring activities, they might help explain observations of population change and provide insights to essential specific habitat requirements. Habitat monitoring of known occurrences would also help alert managers of new impacts such as ORV damage and trampling. Changes in environmental variables might not cause observable demographic repercussions for several years, so re-sampling the chosen variables may help to identify underlying causes of population trends. Evidence of current land use practices and management are important to document during monitoring.

Management actions that reduce impacts to *Saussurea weberi* and its habitat will benefit the species. Most occurrences are not known to be in need of changes in management at this time, but management actions at some locations could prevent the loss of occurrences in the future. Fire is unlikely to harm or benefit *S. weberi* directly since fire is rare in its habitat of alpine solifluction lobes and scree/talus slopes (Johnston personal communication 2003).

Livestock management practices that limit or prohibit grazing within occurrences of *Saussurea weberi* may be of benefit to the species, although the species is not known to be grazed. The primary threat to *S. weberi* from grazing is likely damage through trampling, with weed invasion posing a secondary threat. Livestock exclosures could be used to prevent sheep and cattle grazing in occupied habitat if problems are anticipated for particular occurrences.

Routing new trails and rerouting any existing trails around known occurrences are probably the best ways to reduce direct human impacts to *Saussurea weberi*.

No seeds or genetic material are currently in storage for *Saussurea weberi* in the National Collection of Endangered Plants maintained by the Center for Plant Conservation (Grant 2003 personal communication). Collection of seeds for long-term storage will be useful if future restoration work is necessary.

The inclusion of all Wyoming and Montana occurrences in wilderness areas, with some additional protection through inclusion in RNAs, is an important conservation measure, particularly since these protected areas encompass the largest known population center for the species.

In Colorado, the Forest Service's Hoosier Ridge RNA and BLM's Mosquito Pass ACEC provide special management status protection to the species. As the largest occurrence in Colorado, the Dolly Varden Gulch site would be a prime candidate for pursuit of a conservation easement. Protection of the largest known occurrence in Colorado might be very important toward maintaining the genetic diversity of *Saussurea weberi*.

Conservation measures adopted in recovery plans for federally listed plant species are generally applicable for *Saussurea weberi*, and in some cases have already been implemented. Measures already implemented include designation of wilderness and RNAs for protection of important occurrences and the initial studies of pollination biology by Abbott (1998). Other typical approaches, not yet implemented for *S. weberi*, include initiating monitoring of select occurrences and collection of seed material for storage.

Information Needs

Distribution

Further species inventory work is among the top priorities for research on *Saussurea weberi*, especially better characterization of its distribution across potential habitat in Colorado. Until its distribution and population size are better defined, it will not be possible to assess the conservation needs and priorities for this species accurately.

Although the entire global distribution of *Saussurea weberi* occurs as disjunct occurrences in Colorado, Wyoming, and Montana, more potential habitat within the general area remains to be searched. In Wyoming, additional unsurveyed potential habitat remains in the Salt River and Gros Ventre ranges (Marriott 1988, 1991) as well as additional small areas of limestone on the Shoshone National Forest's Wind River and Absaroka ranges (Scott personal communication 2003). In Colorado, a great deal of potential habitat may be present in other areas with alpine limestone, including portions of the Sawatch Range on the Gunnison National Forest (Johnston personal communication 2003) and on the San Juan National Forest. Revisiting and assessing the historic occurrences is also needed, especially those that have not been observed in the last 10 years. More refined habitat information will help focus future search efforts.

Lifecycle, habitat and population trend

Very little is known about the population ecology of *Saussurea weberi*. Population estimates are available for about half of the occurrences, but there are no monitoring data with which to determine the population trend, with the exception of Abbott's ongoing study of the Horseshoe Cirque occurrence. Basic life history parameters need to be determined from which the viability of populations can be inferred. Assessing the overall population trend across multiple occurrences is also among the top research priorities for this species.

Substantial work in the late 1980s in Wyoming resulted in location of new occurrences, and provided basic information on population size, associated species, and habitat of *Saussurea weberi*. Further work is needed to quantify more rigorously population sizes, to attempt to observe population trend, and to better characterize habitat requirements. Assessing the overall population trend is one of the most important priorities for further research.

Autecological research is needed for *Saussurea weberi* to better define important habitat characteristics and provide insights as to why many apparently suitable sites are not occupied. Ordination of species associations might identify community types or species closely associated with *S. weberi*. Element Occurrence Records suggest *S. weberi* may be positively associated with several rare taxa, including *Androsace chamaejasme* var. *carinata*, *Braya humilis*, *Erigeron lanatus*, *Erigeron radicans*, and *Parrya nudicaulis*. Information on soil chemistry and nutrient relations, as well as further pollination studies, might yield valuable insights into the ecological requirements of *S. weberi*, which would in turn create opportunities for effective habitat monitoring and conservation stewardship of this species. Physiological ecology studies will help determine what substrate characteristics are required by *S. weberi*; this is valuable information in the event that an occurrence needs to be restored and for further modeling the potential distribution of the species.

Response to change

Abbott's study of the Horseshoe Cirque occurrence indicates *Saussurea weberi* individuals are relatively long-lived (i.e., nine to ten years, possibly longer). However, other basic aspects of the species' ecology, such as rates of reproduction, dispersal, germination, and establishment and the effects of environmental variation and disturbance on these parameters have not been investigated. This lack of information potentially limits the assessment of management options during project planning. While there is no evidence of disturbance-related impacts to *S. weberi*, it is not expected to tolerate heavy disturbance. An assessment of potential impacts from livestock and mountain goats would verify whether or not threats from these animals are of concern. Herbivory by mountain goats may not play an important role in the ecology of *S. weberi* based on observations to date, but this has not been formally assessed.

A better understanding of the pollination and breeding ecology of *Saussurea weberi* will assist managers by determining the importance of pollinators for reproduction and population genetics across its range. At this time, it is not known how management changes that affect insect visitors will affect *S. weberi*, although activities that disrupt bumblebees would likely be detrimental. Following up on the work by Abbott and Spackman et al. 2001 would provide additional insights into pollination and reproductive ecology.

While no invasive species concerns have been noted for *Saussurea weberi*, it can be assumed that

management changes that promote the spread and abundance of invasive species in the vicinity of *S. weberi* populations will be detrimental. Population monitoring efforts should include occurrences near areas that have been invaded by invasive species. This might allow for tracking of incipient weed encroachment, and would provide valuable ecological information and insights into appropriate management strategies.

Metapopulation dynamics

There has been no research on the population ecology of *Saussurea weberi* to determine the importance of metapopulation structure and dynamics to the long-term persistence of *S. weberi* at local or regional scales. Migration, extinction, and colonization rates are unknown for *S. weberi*, so analyses of local or regional population viability are dependent on observable trends in individual populations.

Demography

Population size has been estimated for some occurrences of *Saussurea weberi*, but not rigorously quantified. In addition, existing knowledge of the distribution of the species is undoubtedly incomplete and there are no data pertaining to growth, survival, and reproduction rates. The work by Abbott (1998) suggests that seed predation by fly larvae may dramatically impact reproductive rates, at least in certain Colorado occurrences. As a result, additional field data are necessary before local and range-wide persistence can be assessed with demographic modeling techniques. According to Abbott (personal communication 2004), Dr. Graham C. D. Griffiths of University of Alberta has determined the maggots responsible for high predation upon achenes of *S. weberi* belong to two closely related species of anthomyiid flies in genus *Botanophila*. According to Abbott (personal communication 2004), Dr. Griffiths is performing a revision of the genus *Botanophila* that might reveal one or both species to be previously undescribed, which might suggest the rare plant species *S. weberi* may in turn host a rare fly predator.

Population trend monitoring methods

Except for Abbott's work, there has been no monitoring of *Saussurea weberi* occurrences, but a variety of methods are available that would provide meaningful insights to population trends, including several approaches discussed herein. Collecting information about life history stages can also be useful for slow-growing, long-lived species such as *S. weberi*.

For instance, it is not known how many years are required to reach reproductive maturity or how long individuals may live.

Restoration methods

No attempts have been made to restore occurrences of *Saussurea weberi*. However, a protocol has been developed for germination and containerized growing of plugs of *S. densa*, another North American species of *Saussurea* that occurs on calcareous alpine slopes in Montana and southwest Canada (Wick et al. 2001). The protocol specifies hand collection of seeds in late August when achenes are grey and easily removed from the disc, followed by hand cleaning. The seeds are sown in an outdoor nursery bed and subjected to a five-month cold moist stratification period. Seeds are then germinated and taken through a four-week establishment phase followed by an eight-week active growth period and a four-week hardening phase, before they can be harvested. Time to harvest is stated as nine months, at which point individual plants have four to six true leaves and the roots fill a 160 ml container (Wick et al. 2001). In Colorado, seed from the Horseshoe Cirque population of *S. weberi* has been successfully germinated in a greenhouse, with a high degree of seedling survival (Abbott 1998). Abbott's unpublished comparative study examined seed germination and seedling survival of *S. weberi* upon three substrates in spring and summer of 1995, from seed collected during September 1994 (Abbott personal communication 2004). According to Abbott, the substrates were: Leadville/Manitou (soil gathered from a location where *S. weberi* grows), Pierre/ Dakota Brule (a plains soil of the same pH as the natural substrate of *S. weberi*), and a custom organic greenhouse mixture. No special treatment was applied to induce germination, other than presoaking fruit on wet filter paper. Less than 20 percent of the seeds planted in Leadville/Manitou soil had germinated by the end of the study. After more than 100 days, no seedlings of *S. weberi* had survived on Leadville/Manitou soil. By comparison, a little over 40 percent of seeds planted on greenhouse mixture had germinated, and 30 percent had survived more than 100 days, while germination and seedling survival on the Pierre/ Dakota Brule soil were about 17 percent and 13 percent, respectively.

Research Priorities for USFS Region 2

Assessment of population trend through collection of monitoring data is an important research priority for USFS Region 2. This information, coupled with

collection of additional baseline habitat and community ecology data for existing and future EORs, will help to provide a better understanding of the absolute habitat requirements and improve the scientific basis for management of *Saussurea weberi* in USFS Region 2. Additional information needs include collection of detailed eco-data, such as cover class estimates of all associated species, bare ground, soil texture classes, canopy cover, and detailed phenologic data for *S. weberi*, (e.g., time of seedling emergence, biomass, flowering period, seed set, ripening, and germination, seedling survival rates, etc.). The protocol by Wick et al. (2001) may offer insights to seed ripening, germination, and growth requirements for *S. weberi*.

Determining once and for all whether or not *Saussurea weberi* is rhizomatous has important implications for its on-going survival and management, and should be prioritized as an initial research objective. The question as to whether or not *S. weberi* is rhizomatous further complicates field observations due to the inability to discern whether or not shoots are physically connected, and thus may represent ramets rather than genetic individuals. This has implications for recognizing seedling recruitment and assessing the genetic make-up of populations, as in Abbott's on-going study. Genetic testing to verify whether or not *S. weberi* is rhizomatous, and if so, the extent to which occurrences are rhizomatous, are important research needs.

Understanding the genetic structure and demographics of *Saussurea weberi* are also among the top research priorities for this species. An assessment of genetic diversity within and between existing occurrences, as well as between the major population centers will provide valuable insights to metapopulation stability and resilience to stochastic events and future environmental change. Demographic research will have great value for management and conservation purposes. If occurrences are robust and contain healthy levels of genetic diversity, demographic studies will help determine how to maintain them with appropriate management. If they are not genetically diverse, awareness of the problem through demographic research will permit development of appropriate management guidelines to address genetic concerns. Some key questions to address are: Are populations stable? Do peripheral populations (such as those in Montana and Colorado) contain unique alleles? What is the minimum viable population size for *S. weberi*? Molecular data would reveal much about the population genetics of individual populations as well and might be suggestive of historic distribution patterns.

Genetic studies (e.g., protein analysis, DNA analysis), including an evaluation of phylogenetic relationships with other North American *Saussurea* species might yield useful information.

The response of *Saussurea weberi* to human impacts and disturbance has not been studied. Gaining practical knowledge of how best to manage occurrences of this species is important to anticipate potential impacts of existing and future land use patterns.

Although *Saussurea weberi* distribution has been relatively well documented, more species inventory work is needed throughout the range of the species. Further attempts to locate occurrences in Colorado are warranted, mainly because the distribution of the species in the state hasn't been well characterized and much apparently suitable habitat remains to be surveyed. The CNHP EORs suggest there is considerable variability in

year to year population size for individual occurrences. If this is true, there is a greater likelihood that previous negative surveys of potential habitat may in fact support *S. weberi*. In Wyoming, not all potential habitat has been searched yet in areas such as the Salt River and Gros Ventre ranges, as well as small areas of the northeast flank of the Wind River Range and the southern end of the Absaroka Range.

Additional research and data resources

Other basic areas of study that are needed include the demography, conservation genetics, pollen cytology, molecular cytogenetics, floral biology, seed viability, and species-environment relationships, including responses to disturbance, of *Saussurea weberi*. Such information would have significant relevance to the conservation and management of this species.

DEFINITIONS

Arachnoid-floccose — having fine, cobwebby or tangled hairs; having tufts of wooly hairs. (Scott 1995).

Frost action — or frost wedging, is the weathering process by which rocks are split and wedged apart by continued freeze-thaw cycles. (Scott 1995).

Monophyletic — in cladistic analyses a natural taxonomic group composed of ancestral species and all of its descendents. Cladistics is a type of analysis of phylogenetic relationships in which taxa are grouped on the basis of shared, derived features. (Walters and Keil 1996).

Nivation — the denudation that occurs around snowfields and meltbanks when sediments are removed from the substrate by meltwater, resulting in a depression or shallow basin. Continued nivation results in an ever-deepening basin, which allows more and more snow to accumulate during the winter. The persistence of this accumulated snow has a profound effect on the distribution of plant species, and late in the season nivation basins are readily detectable by changes in vegetation patterns. (Scott 1995).

Phyllary — one of the involucre bract of the head of a member of the Asteraceae. (Walters and Keil 1996).

Septate — having one or more internal septa or cross partitions. (Walters and Keil 1996).

Solifluction — Geologic process in alpine environments that involves the slow, downslope creep of water-saturated soils and rocks over permafrost, creating starlike lobes of varying sizes that extend across slopes. Changes in slope and exposure (aspect) brought about by solifluction create microenvironments often detectable by the changes in species composition of vegetation mats. (Scott 1995).

Status and Imperilment Ranks used by Federal agencies, Natural Heritage Programs, Natural Heritage Inventories, Natural Diversity Databases, and NatureServe:

FEDERAL STATUS:

1. U.S. Fish and Wildlife Service

- ❖ **E** — Endangered: taxa formally listed as endangered.
- ❖ **T** — Threatened: taxa formally listed as threatened.
- ❖ **C** — Candidate: taxa for which the Service has on file sufficient information on biological vulnerability and threat(s) to support proposals to list them as endangered or threatened species.
- ❖ **(C1) FORMERLY:** Notice of Review, Category 1: taxa for which substantial biological information exists on file to support proposing to list as endangered or threatened.
- ❖ **(C2) FORMERLY:** Notice of Review, Category 2: taxa for which current information indicates that proposing to list as endangered or threatened is possible, but appropriate or substantial biological information is not on file to support an immediate rulemaking.
- ❖ **(C2*) FORMERLY:** Taxa believed to be possibly extirpated in the wild.
- ❖ **(3A) FORMERLY:** Taxa for which the USFWS has persuasive evidence of extinction.

- ❖ **(3B) FORMERLY:** Names that based on current taxonomic knowledge do not represent taxa meeting the Endangered Species Act's definition of a species.
- ❖ **(3C) FORMERLY:** Notice of Review, Category 3C: taxa that have proven to be more abundant or widespread than was previously believed, and/or those that are not subject to any identifiable threat.

2. U.S. Forest Service

- ❖ **S** — Sensitive: those plant and animal species identified by the Regional Forester for which population viability is a concern as evidenced by:
 - A. Significant current or predicted downward trends in population numbers or density.
 - B. Significant current or predicted downward trends in habitat capability that would reduce a species' existing distribution.

The status of species on Forest Service lands is defined by the U.S. Forest Service manual (2670.22). These taxa are designated as such by the Regional Forester (Northern Region) on national forests in Montana as either:

Sensitive	Species, subspecies or variety, for which the Regional Forester has determined there is a concern for population viability rangewide or in the region (also referred to as Type 2 scale of risk for rangewide imperilment, and Type 3 scale of risk for regional imperilment).
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3. Bureau of Land Management

- ❖ **S** — Sensitive: those species found on public lands, designated by a State Director, that could easily become endangered or extinct in a State. The protection provided for sensitive species is the same as that provided for C1 and C2 candidate species.

THE NATURE CONSERVANCY NATURAL HERITAGE RANKS:

Global Rank (G): based on range-wide status of a species

- ❖ **G1** Critically imperiled globally because of extreme rarity (5 or fewer occurrences, or very few remaining individuals), or because of some factor of its biology making it especially vulnerable to extinction. (Critically endangered throughout its range).
- ❖ **G2** Imperiled globally because of rarity (6 to 20 occurrences) or because of other factors demonstrably making it very vulnerable to extinction throughout its range. (Endangered throughout its range).
- ❖ **G3** Vulnerable throughout its range or found locally in a restricted range (21 to 100 occurrences). (Threatened throughout its range).
- ❖ **G4** Apparently secure globally, though it might be quite rare in parts of its range, especially at the periphery.
- ❖ **G5** Demonstrably secure globally, though it may be quite rare in parts of its range, especially at the periphery.
- ❖ **GX** Presumed extinct
- ❖ **GQ** Indicates uncertainty about taxonomic status.

- ❖ **GU** Unable to assign rank due to lack of available information.
- ❖ **G?** Indicates uncertainty about an assigned global rank.

Trinomial Rank (T): used for subspecies or varieties. These taxa are ranked on the same criteria as G1-G5.

State rank (S): based on the status of a species in an individual state. S ranks may differ between states based on the relative abundance of a species in each state.

- ❖ **S1** Critically imperiled in state because of extreme rarity (5 or fewer occurrences, or very few remaining individuals, or because of some factor of its biology making it especially vulnerable to extirpation from the state. (Critically endangered in state).
- ❖ **S2** Imperiled in state because of rarity (6 to 20 occurrences) or because of other factors demonstrably making it very vulnerable to extirpation from the state. (Endangered or threatened in state).
- ❖ **S3** Vulnerable in state (21 to 100 occurrences).
- ❖ **S?** Indicates uncertainty about an assigned state rank.
- ❖ **SH** Of historical occurrence

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